UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF PREVENTION, PESTICIDES, AND TOXIC SUBSTANCES
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MEMORANDUM

SUBJECT: **2,4-D:** 2nd Revised Occupational and Residential Exposure and Risk Assessment and Response to Public Comments for the Registration Eligibility Decision (RED) Document [PC Code 030001, DP Barcode D310491]

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Attached is the Occupational and Residential Exposure and Risk Assessment document for the 2,4-D RED Chapter. This document has been revised as appropriate to address public comments. Most of the revisions were made in the sections of the document that deal with the risks of swimming in water bodies treated with 2,4-D.

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Executive Summary

2,4-D Product Descriptions, Uses and Application Methods:

There are registered products of 2,4-D for both occupational and residential site applications. The registered agricultural uses include field/row crops, orchard floors, vineyard floors, and sod farm turf. Residential uses include broadcast and spot treatment on turf. The acid, dimethylamine and ethylhexyl ester forms of 2,4-D account for the most products. Most of the 2,4-D products are formulated as liquids or granules, although a few of the acid and salt forms are also formulated as water soluble powders. The residential products are typically formulated as dry weed and feed products or as liquids in concentrates or ready to use sprays. The 2,4-D master label has been developed by the 2,4-D task force and represents the maximum application rates for agricultural and non-agricultural uses. Some of the rates are lower than the rates present on existing labels, however, the agency and the task force have agreed that the existing labels will be updated with the new rates as part of the re-registration process.

Typically one to three applications are made per growing season. Applications are made to the target weeds prior to crop emergence, after crop emergence, prior to harvest and in the dormant season, depending upon the crop. The 2,4-D labels allow ground and aerial application, however, they do not allow chemigation. Ground applications are made whenever possible due to cost and convenience while aerial applications are primarily made to rice fields that are flooded or to rangeland areas where woody weeds are too tall for a tractor (2,4-D Smart Meeting, 2001). Aquatic areas can treated from boats either by spraying the floating weeds or by applying liquid or granular materials to submerged weeds. Forestry applications can be made by rotary winged aircraft (i.e. helicopters) for large scale conifer release programs or by backpack for smaller areas such as Christmas tree plantations.

Toxicology Endpoints:

The following endpoints as selected by the HIARC (US EPA, May 1, 2003) were used for assessing 2,4-D risks:

- A NOAEL of 67 mg/kg/day was selected from an acute neurotoxicity study in rats during which in-coordination and slight gait abnormalities were observed. This NOAEL is applicable to acute incidental oral and dermal exposures.

- A NOAEL of 25 mg/kg/day was selected from a developmental oral study in rats during which developmental (skeletal variations) and maternal (decreased body weight gain) effects were observed. This NOAEL is applicable to short term incidental oral, dermal and inhalation exposures.

- A NOAEL of 15 mg/kg/day was selected from a sub-chronic oral study in rats during which decreased body weight/body weight gain, alterations in hematology and clinical chemistry parameters and cataract formation were observed. This NOAEL is applicable to intermediate term incidental oral, dermal and inhalation exposures.

- A dermal absorption factor of 5.8 percent was selected for converting dermal exposures to oral equivalent doses. An inhalation absorption factor of 100 percent was selected for converting inhalation exposures to oral equivalent doses.

Endpoints were also selected by the HIARC for chronic exposures, however, these endpoints were not used in this assessment because chronic occupational and residential exposures to 2,4-D are not expected to occur. 2,4-D is only applied a couple of times each year during the growing season, rapidly dissipates from the foliage and is readily excreted from the human body.

The target MOE for occupational populations is 100 which includes the standard uncertainty factors of 10X for intraspecies variability (i.e. differences among humans) and 10X for interspecies variability (differences between humans and animals). The target MOE for residential populations is 1000 because it also includes a database uncertainty factor of 10X. The HIARC determined that this factor is needed due the lack of certain studies since the available data provide no basis to support reduction or removal of the default 10X factor.

Occupational Handler/Applicator Exposure and Risk Estimates:

The non-cancer risks (i.e. MOEs) for occupational exposures were calculated for short and intermediate term dermal and inhalation exposures using standard assumptions and unit exposure data for a wide range of application methods and equipment. The standard assumptions, such as acres treated per day, were taken from ExpoSAC SOPs. The unit exposure data were taken from PHED, the ORETF studies for professional lawn care operators and a California DPR study for backpack applicators. With the exception of mixing/loading wettable powder, most of the MOEs exceed the target of 100 with baseline or single layer PPE and are not of concern. This level of PPE is generally consistent with the labels which typically require coveralls and gloves. The MOEs for handling wettable powder are acceptable with engineering controls (i.e. water soluble bags). Only a few 2,4-D products are formulated as wettable powders and almost all of these products are packaged in water soluble bags.

Post-Application Occupational Exposure and Risk Estimates:

2,4-D, which is highly selective for broadleaf weeds, can cause leaf damage to some of the labeled broadleaf crops and the labels specify that it should be applied to the ground in such a manner as to minimize crop damage. To provide weed control without damaging the crops, applications are made in the dormant season or prior to planting, sprays are directed to the row middles or orchard floors and drop booms and/or shields are used to prevent crop contact. Broadcast applications can be made to grass crops such cereal grains, rice and sugarcane which are tolerant of 2,4-D. Given the above characteristics of 2,4-D, it is anticipated that post application exposures would primarily occur following treatment of the grass crops.

MOEs were calculated for short and intermediate term post application exposures using standard assumptions, standard transfer coefficients and the TTR data. All of the MOEs are above 100 on day zero which indicates that the risks are not of concern. The WPS REI ranges from 12 to 48 hours depending upon the form of 2,4-D.

Residential Applicator Exposure and Risk Estimates:

The residential products are typically formulated as dry weed and feed products or as liquids in concentrates or ready to use sprays. Many of these formulations include other phenoxy herbicides such as MCPP-p and MCPA. Both spot and broadcast treatments are included on the labels. Exposures are expected to be short term in duration for broadcast treatments because the label allows only two broadcast treatments per year. Exposures are also expected to be short term in duration for spot treatments because the labels recommend repeat applications for hard to kill weeds in two to three weeks.

The MOEs for residential handlers exposures were calculated using standard assumptions, master label rates and PHED and ORETF unit exposure data. All of the MOEs exceed the target MOE of 1000 and are not of concern.

Data Used for Turf Post Application Exposure Assessment

There are three turf transferable residue studies that were submitted by the Broadleaf Turf Herbicide TTR Task Force. These studies measured the dissipation of several phenoxy herbicides, including 2,4-D, using the ORETF roller technique (which is also called the modified California Roller). The studies have been reviewed by HED and were found to meet all of the series 875 guidelines for postapplication exposure monitoring.

The purpose of the first study was to assess the effects of the different chemical forms upon the day zero turf transferable residues (TTR) and dissipation rates of phenoxy herbicides including 2,4-D. This study indicated that the DMA form of 2,4-D had the highest transferability of 2.9 percent. The half lives ranged from 0.53 days to 1.2 days and no rain occurred.

The purpose of the second study was to assess the effects of different spray volumes upon the day zero TTRs and dissipation rates of phenoxy herbicides. The day zero TTRs ranged from 0.87 to 1.3 percent and were generally greater than the DAY 1 TTRs. The half lives were fairly consistent and were short (0.30 days) because rain occurred on Day 2 and 3.

The purpose of third study was to assess the effects of two additional sites (California and Wisconsin) upon the day zero TTRs and dissipation rates. The TTRs declined to the LOQ by DAT 1 in Wisconsin due to rain. The TTRs remained above the LOQ at the California site because no rain occurred and the halflife was 2.7 days.

Residential Turf Post Application Exposure and Risk Estimates

The MOEs for residential turf exposures were calculated using the TTR data, master label rates and the Residential SOPs. MOEs were calculated for acute exposures using the maximum TTR value of 2.9 percent of the application rate along with the acute NOAEL. MOEs for toddler short term exposures were calculated using the seven day average TTR values because the short term NOAEL was based upon decreased body weight gain which occurred after several days of exposure. MOEs for adult short term exposures were calculated using the maximum TTR value because the short term NOAEL is based upon developmental effects that could have occurred following one day of exposure. All of the MOEs meet or exceed the target MOE of 1000.

The results of a biomonitoring study (Harris and Solomon 1992) were also used to calculate dermal MOEs for post application exposure on turf. The study was conducted with adult volunteers who were exposed to 2,4-D while performing controlled activities for one hour on turf treated with 2,4-D. The controlled activities were conducted at 1 hour after treatment (HAT) and at 24 HAT. Ten volunteers participated in the study. Five volunteers wore long pants, a tee shirt, socks and closed footwear. The other five wore shorts and a tee shirt and were barefoot. The volunteers walked on the turf for a period of 5 minutes and then sat or lay on the area for 5 minutes and then continued in this fashion for 50 more minutes. Each volunteer collected all urine for the next 96 hours immediately following the exposure. The MOEs for the DAT 1 volunteers who wore shorts and no shoes ranged from 1000 to 26000 with the lowest MOE corresponding to the volunteer who removed his shirt during the exposure period. The MOEs for the remaining volunteers ranged from 17000 to 27000.

Recreational Swimmer Post Application Exposure and Risk Estimates

The master label indicates that 2,4-D can be used for aquatic weed control of surface weeds such as Water Hyacinth and submersed weeds such as Eurasian Milfoil. Surface weeds are controlled by foliar applications at a maximum rate of 2.0 lbs ae/acre. Submersed weeds are controlled by the subsurface injection of liquids or the application of slow dissolving granules and the maximum application rate is 10.8 lb ae per acre foot which yields a water concentration of 4 ppm. Although the probability that a person would swim in an area recently treated for milfoil is low because the presence of milfoil usually makes swimming difficult, swimmer exposures were assessed because exposures could occur after follow-up treatments in the mid-summer when the milfoil has been partially controlled.

Because the 2,4-D water concentrations can vary depending upon the application rate and site conditions, the Maximum Swimming Water Concentration (MSWC) was calculated. The MCWC is the water concentration at which the combined dermal and ingestion MOE meets or exceeds the target MOE of 1000. The MSWCs were calculated for children's acute exposures using the acute NOAEL of 67 mg/kg/day and the MSWCS for children's short term exposures were calculated using the short term NOAEL of 25 mg/kg/day for maternal effects. The MSWCs for adult acute/short term exposures were calculated using NOAEL of 25 mg/kg/day that is based upon the developmental effects which could have occurred following one day of exposure. The acute MSWCs range from 1.2 ppm for 2,4-D BEE to 9.8 ppm for 2,4-D acid while the short term MSWCs range from 0.9 ppm for 2,4-D BEE to 3.6 ppm for 2,4-D acid or amine. The MSWCs for 2,4-D BEE are lower because 2,4-D BEE has a much higher dermal rate.

The Acute MSWC of 9.8 ppm for exposures to 2,4-D acid or amine is greater than the master label application rate of 4.0 ppm, therefore, acute exposures to acid or amine are not of concern. The short term MSWC of 3.6 ppm for short term exposures to acid or amine is also not of concern because some dissipation or dispersion is likely to occur which would cause the 7 day average 2,4-D concentration to be less than 3.6 ppm. Dissipation studies submitted to EFED indicated that the half lives following pond and lake liquid treatments ranged from 3.2 days to 27.8 days which yield 7 day average concentrations of 1.9 ppm when the half life equals 3.2 days to 3.6 ppm when the half life equals 27.8 days.

The MSWCs for 2,4-D BEE are less than the master label application rate of 4 ppm, but they are unlikely to be of concern because 2,4-D BEE degrades rapidly to 2,4-D acid, which has a much lower rate of dermal absorption. The existing label rates for 2,4-D BEE products are also lower than the master label rate.

Incident Reports

The incident report was prepared by the HED Chemistry and Exposure Branch (US EPA, 2004). A total of 45 incidents were reported in the OPP Incident Data System and many of these incidents involved irritant effects to the eyes, skin and occasionally respiratory passages. Poison Control Center Incident Data (1993 to1998) indicated that 2,4-D is generally less likely than other pesticides to cause minor, moderate or life threatening symptoms. The most common symptoms were dermal irritation and ocular problems. Incident data from CA DPR indicated that the number of cases generally ranges from 0 to 3 per year and most of these cases were due to eye or skin effects. Incident data from the National Pesticide Information center for the years 1996 to 2002 indicated that an average of 3 cases definitely or probably related to 2,4-D exposure were reported per year.

Risk Characterization

The occupational handler risks are mainly of concern when handling 2,4-D as a wettable powder without engineering controls (i.e. the powder is not in water soluble bags). Only a few 2,4-D products are formulated as wettable powders and most of these products are packaged in water soluble bags.

The occupational post application MOEs are above the target MOE of 100 on day zero and many are greater than 1000 which means that the risks are generally low.

The master label application rate of 2.0 lb ae/acre was used for the residential handler and post application turf assessments. Many of the labels have application rates in the range of 0.5 to 1.5 lb ae/acre because 2,4-D is formulated with other phenoxy herbicides such as MCPP-p and MCPA.

1.0 Background Information

1.1 Purpose and Criteria for Conducting Exposure Assessments

Occupational and residential exposure and risk assessments are required for an active ingredient if: (1) certain toxicological criteria are triggered **and** (2) there is potential exposure to handlers (i.e., mixers, loaders, applicators, etc.) during use or to persons entering treated areas after application is completed. 2,4-D (2,4-dichlorophenoxy acetic acid; CAS # 94-75-7) meets both criteria. There is potential exposure to private growers and custom applicators from agricultural site applications of 2,4-D. In addition, the general public may be exposed to 2,4-D during or after application to residential lawns.

2,4-D is produced in various forms including acid, sodium salt, amine salts and esters. A listing of these forms is included in Table 1.

Table 1 - 2,4-D Forms

2,4-D Form	PC CODE
2,4-D Acid	030001
2,4-D Sodium Salt	030004
2,4-D diethanolamine salt (DEA)	030016
2,4-D dimethylamine salt (DMA)	030019
2,4-D isopropylamine salt (IPA)	030025
2,4-D trisisopropanolamine (TIPA)	030035
2,4-D 2-butoxyethyl ester (BEE)	030053
2,4-D 2-ethylhexyl ester (2-EHE)	030063
2,4-D isopropyl ester (IPE)	030066

Many of the 2,4-D products also contain other phenoxy herbicides such as MCPA and MCPP-p. These herbicides are not addressed in this risk assessment.

1.2 Acute Toxicity and Endpoints Used for Risk Assessment

Acute Toxicity

The results of acute toxicity testing are summarized in Table 2. The sodium salt, IPE, BEE and EHE forms of 2,4-D are mild to moderate eye irritants (i.e. Toxicity Category III) while all of the other forms are severe eye irritants (i.e. Toxicity Category I). All of the forms are of moderate toxicity (Tox III) via oral and dermal exposure. With the exception of the BEE ester, all of the forms are of low toxicity (Tox IV) for primary skin irritation. None of the forms are dermal sensitizers.

Table 2 - Acute Toxicity Categories for the Various Forms of 2,4-D

	2 ,4-D Form								
Guideline (Number)	**Acid**	**Sodium Salt**	**DEA**	**DMA**	**IPA**	**IPE**	**TIPA**	**BEE**	**2-EHE**
Acute Oral (870.1100)	III	III	III	III	III	III	III	III	III
Acute Dermal (870.1200)	III	III	III	III	III	III	III	III	III
Acute Inhalation (870.1300)	III	No Data	IV	IV	IV	IV	IV	IV	IV
Primary Eye Irritation (870.2400)	I	III	I	I	I	III	I	III	III
Primary Skin Irritation (870.2500)	IV	IV	IV	IV	IV	IV	IV	III	IV
Dermal Sensitization (870.2600)	Not a dermal sensitizer - all forms								
Note: The acute toxicity categories range from I which is the most toxic to IV which is the least toxic.									

Toxicological Endpoints Used for ORE Risk Assessment

The toxicological endpoints that were used to complete occupational and residential exposure assessments are summarized in Table 3. These endpoints were selected from animal studies by the HIARC and are discussed in detail in HED Document #0051866 of May 1, 2003.

The combined uncertainty factor which defines the target MOE for occupational populations is 100 which includes the standard safety factors of 10X for intraspecies variability (i.e. differences among humans) and 10X for interspecies variability (differences between humans and animals). The target MOE for residential populations is 1000 because it also includes a database uncertainty factor of 10X. The HIARC determined that this factor is needed due the lack of certain studies since the available data provide no basis to support reduction or removal of the default 10X factor. These studies include a developmental neurotoxicity study and a repeat of 2-generation reproduction study using the new protocol.

Table 3 - 2,4-D Toxicology Endpoints Used for ORE Assessment				
EXPOSURE SCENARIO	**DOSE (mg/kg/day)**	**ENDPOINT (NOAEL/LOAEL = mg/kg/day)**	**TARGET MOE**	**STUDY**
Acute Dietary (Females 13-50 years of age)	NOAEL= 25 Developmental toxicity	Skeletal malformations and variations with a LOAEL of 75.	100 = O 1000 = R	Developmental rat study
Acute Dietary General Population	NOAEL = 67	Gait abnormalities with a LOAEL of 227. The NOAEL for systemic toxicity was 227[the highest dose tested].	1000 = R	Acute Nuerotoxicity in rats
Short Term Dermal, Inhalation and Incidental Oral	NOAEL= 25 Maternal and Developmental toxicity	Developmental - skeletal malformations and variations with a LOAEL of 75. Maternal - Decreased weight gain with a LOAEL of 75.	100 = O 1000 = R	Developmental rat study
Intermediate Term Dermal, Inhalation and Incidental Oral	NOAEL = 15	Decreased body weight/body-weight gain, alterations in some hematology [decreased platelets] and clinical chemistry [decreased T_3 and T_4] parameters, and cataract formation with a LOAEL of 100.	100 = O 1000 = R	Sub-chronic oral study in rats
Long Term Dermal, Inhalation and Incidental Oral	NOAEL = 5.0	Decreased body weight/body-weight gain, alterations in hematology, clinical chemistry parameters, increased kidney weights, degeneration of the descending proximal tubules, hepatocellular hypertrophy, lung inflammation and adipose tissue atrophy with a LOAEL of 75. At the high-dose level, there also were microscopic lesions in the eyes, liver, testes, thyroid, and lungs.	100 = O 1000 = R	Chronic oral toxicity study in rats
Notes 1. Oral endpoint were used for dermal exposure, therefore a dermal absorption factor of 5.8% of oral exposure was used. 2. Oral endpoints were used for inhalation exposure, therefore inhalation exposure was assumed to be equivalent to oral exposure. 3. The target MOE is 100 for occupational populations (O) and 1000 for residential populations (R).				

Carcinogenicity of 2,4-D

The HED Carcinogenicity Assessment Review Committee (CARC) concluded that 2,4-D "should remain classified as a group D - Not Classifiable as to Human Carcinogenicity. That is, the evidence is inadequate and cannot be interpreted as showing either the presence or absence of a carcinogenic effect." This conclusion is discussed in the EPA/OPP Memorandum "Carcinogenicity Peer Review (4^{th}) of 2,4-Dichlorophenoxyacetic acid", TXR #005017 of January 29, 1997. This memo also states that "Overall, the pattern of responses observed in both in vitro and in vivo tests indicated that 2,4-D was not mutagenic (although some cytogenic effects were observed)".

1.3 Incident Report

The incident report was prepared by the HED Chemistry and Exposure Branch (US EPA, 2004). A total of 45 incidents were reported in the OPP Incident Data System. Many of these incidents involved irritant effects to the eyes, skin and occasionally respiratory passages. Poison Control Center Incident Data (1993 to1998) indicated that 2,4-D is generally less likely than other pesticides to cause minor, moderate or life threatening symptoms. The most common symptoms were dermal irritation and ocular problems.

There were 33 cases reported in the California Pesticide Illness Surveillance Program for the years 1982-2001 where 2,4-D was used alone or was judged to be responsible for the health effects. With the exception of 1989 when seven cases were reported, the number of cases per year ranged from 0 to 3. Of the 33 cases, 13 were due to systemic effects, 18 were due to eye or skin effects, 1 was due to respiratory effects and 1 was due a combination of effects. Seven of the 13 systemic cases occurred in 1989. Twenty two of the cases involved pesticide handling (mixing, loading, application or storage), seven involved drift, one case involved field worker exposure and 3 cases involved unspecified exposures. Many of the handler cases occurred during equipment cleaning or repair or when a hose broke. Six of the seven drift cases involved a helicopter application that violated label instructions.

According to the National Pesticide Information center, 2,4-D was number 8 in terms of calls received with a total of 429 incidents reported in humans and 108 incidents reported in animals (mostly pets) during the years 1984 to 1991. A similar pattern was also observed during the years 1996 to 2002 when a total of 368 incidents were reported in humans and 206 incidents were reported in animals. Of the incidents reported from 1996 to 2002, 19 incidents in humans and 3 incidents in animals were considered to be definite or probable.

The incident report includes a review of the incidents reported in the literature. Many of these incidents were the result of accidental or intentional ingestion of relatively large amounts of 2,4-D and some resulted in death due to renal failure, acidosis and electrolyte imbalance. Single doses of 5 mg/kg/day have been administered to human subjects without adverse affects and one subject consumed 500 mg per day for 3 week without experiencing symptoms or signs of illness. Neurotoxic effects such as peripheral neuropathy have been observed following dermal exposures, however, it is not certain that exposures to other neurotoxicants, such as solvents, were entirely excluded.

The incident report concludes with the following recommendations: (1) Dermal PPE may be important not only to prevent minor dermal irritant effects, but also long term effects of the muscles. Labels should clearly warn that significant amounts of 2,4-D spilled on the skin should be rinsed off with copious amounts of soap and water immediately after exposure. (2) Eye protection for both occupational and residential users is warranted because a large number of problems have occurred among workers and residential users who got 2,4-D in their eyes.

1.4. Summary of Use Patterns, Formulations and Application Methods

Uses

The 2,4-D Task Force has developed a Master Label for Reregistration of 2,4-D Uses (2,4-D Master Label, 2003) and SRRD has determined that this label will be used for risk assessment (EPA, 2003). There are registered, supported products of 2,4-D intended for both occupational and residential site applications. The registered agricultural uses include field /row crops, orchard floors, vineyard floors, and sod farm turf. Residential uses include broadcast and spot treatment on turf.

Based upon available pesticide survey usage information for the years 1992-2000, the Biological and Economic Effects Division (BEAD) of EPA estimates that total annual domestic usage for agricultural applications of 2,4-D is approximately 30 million pounds active ingredient (ai). Based upon information for the years 1993-1999, BEAD estimates that total annual domestic usage for non-agricultural applications of 2,4-D is approximately 16 million pounds ai. A listing of the use sites with the largest amounts of 2,4-D used and/or the highest percent crop treated is given in Table 4.

Table 4 - Qualitative Usage Analysis Summary for 2,4-D

Use Site	**Amount Used (pounds)**	**Percent of Total Amount Used**	**Percent Crop Treated**
Pasture/Rangeland	11 million	37%	3%
Spring Wheat	3.8 million	13%	51%
Winter Wheat	3.3 million	11%	15%
Field Corn	2.9 million	9.7%	9%
Soybeans	1.7 million	5.7%	5%
Fallow, Summer	1.4 million	4.7%	7%
Filberts	26,000	0.087%	49%
Sugar cane	335,000	1.1%	36%
Barley	1 million	3.3%	36%
Total Agriculture	30 million		
Lawns by Homeowner	8.3 million	52%	
Lawns by PCO	3.2 million	20%	
Roadways/Rights of Way	1.4 million	7.0%	
Total Non-Agriculture	16 million		
Source: QUA Report for 2,4-D, EPA BEAD, 8/9/01.			

Mode of Action and Targets Controlled

2,4-D is a highly selective herbicide that is used mainly for post emergence control of certain broadleaf weeds and woody plants. It is translocated throughout the weed plant and has a complex mechanism of action resembling those of auxins (growth hormones) and affects cellular division, activates phosphate metabolism, and modifies nucleic acid metabolism (Ware 2000). It is well tolerated by grass crops such as small grains, however, it can be highly damaging to broadleaf crops.

Formulation Types and Percent Active Ingredient

According to EPA OPP REFS label tracking system, as of 01/29/03 there are approximately 600 active products of 2,4-D formulated from 9 different forms. A listing of these forms is included in Table 5. The acid, DMA and 2-EHE forms of 2,4-D have the most products. Most of the 2,4-D products are formulated as liquids or granules, although a few of the acid and salt forms are also formulated as wettable powders. The residential products are typically formulated as dry weed and feed products or as liquids in concentrates or ready to use sprays.

Table 5 - 2,4-D Forms and Number of Labels

2,4-D Form	PC CODE	Number of Labels	Predominant Formulations	Other Formulations
Acid	030001	100	Liquids and granulars	Wettable Powder (8 labels)
Sodium Salt	030004	7	granular	Wettable Powder (1 label)
DEA	030016	3	Liquids	None
DMA	030019	342	Liquids and granulars	Wettable Powder (4 labels)
IPA	030025	8	Liquids	None
TIPA	030035	20	Liquids and granulars	None
BEE	030053	14	Liquids and granulars	None
2-EHE	030063	111	Liquids and granulars	None
IPE	030066	5	Liquids	None

Application Rates, Timing and Frequency of Applications

The 2,4-D master label has been developed by the 2,4-D task force and represents the maximum application rates for agricultural and non-agricultural uses. Some of the rates are lower than the rates present on existing labels, however, the agency and the task force have agreed that all of the 2,4-D the labels will be updated with the new rates as part of the registration process. It was also decided that all of the registrants, including those that are not in the 2,4-D task force, will have to conform to the master label rates. The master label agreement is discussed in a memo from SRRD to EFED and HED (EPA, March 18, 2003).

Typically one to three applications are made per growing season. Applications are made to the target weeds prior to crop emergence, after crop emergence, prior to harvest and in the dormant season, depending upon the crop. The label required spray volumes for ground applications range from 20 gallons for most crops to 400 gallons per acre for brush control. 2,4-D can be applied over the top to tolerant crops such as small grains and rice, but must be directed or shielded for the more sensitive crops such as fruits and berries.

The application rates as taken from the master label are included in Table 6 for non-crop areas and Table 7 for agricultural crops. The average application rates from the 2,4-D QUA report (EPA BEAD 2001) are shown for comparison. With the exception of filberts, the QUA data indicate that only one application is made to most crops. The National Agricultural Pesticide Impact Assessment Program (NAPIAP) report on Phenoxy Herbicides indicates that one 2,4-D application is made annually to turfgrass.

Table 6 - 2,4-D Application Rates for Non-Crop Areas

Aquatic Areas, Forestry, Non-Crop Areas and Turf	**Acid Equivalent (ae) Application Rates Per Application/Per crop or Year**	
	Master Label	**Amount Used per QUA Report**
Aquatic Areas - Floating Weeds	2.0/4.0 per acre	512,000 lbs[1]
Aquatic Areas - Submerged Weeds	10.8 per acre foot	
Tree and Brush Control - Tree Injection	1 to 2 ml per inch of trunk diameter	136,000 lbs
Forestry - Weed and Brush Control	4.0/4.0 per acre	
Forestry - Conifer Release	4.0/4.0 per acre	
Irrigation Ditch Banks	2.0/4.0 per acre	
Rights of Way Areas	2.0/4.0 per acre	2.1 million lbs
Rangeland, Pastures	2.0/4.0 per acre	
Turf - Grass Grown for Seed or Sod	2.0/4.0 per acre	351,000 lbs
Turf - Ornamental	2.0/4.0 per acre	11.6 million lbs

1. According to the NAPIAP report 97789 acres were treated for floating weeds and 4652 acres were treated for submerged weeds by state agencies in 1993.

Table 7 - 2,4-D Application Rates for Agricultural Crops		
Agricultural Crops	**Acid Equivalent (ae) Application Rates per Acre Per Application/Per crop or Year**	
	Master Label	**Average Rate per QUA Report**
Asparagus	2.0/4.0	1.1/1.3
Blueberries - Low Bush Wiper Bar	0.0375 lb/GA	0.46/0.51
Blueberries - High Bush	1.4/2.8	
Citrus (Growth Regulator)	0.1	No Data
Conifer Plantations	4.0/4.0	No Data
Corn (sweet) Corn (field and pop)	0.5 to 1.0/1.5 0.5 to 1.5/3.0	0.48/0.51 0.44/0.46
Cranberries - granular applications Cranberries - liquid applications	4.0/4.0 dormant season application 1.2/2.4 growing season application	1.8/2.0
Fallowland and Crop Stubble	2.0/4.0	0.69/0.89
Filberts	1.0 lb per 100 Ga/4 Apps per year	0.64/1.7
Grain Sorgum	0.5 to 1.0/1.0	0.46/0.50
Grapes	1.36/1.36	0.73/0.87
Orchard Floors (Pome and Stone Fruits, Tree Nuts)	2.0/4.0	Apples = 1.2/1.4 Pears = 1.1/1.5
Potatoes	0.07/0.14	0.10/0.17
Rice	1.0 or 1.5/1.5	0.92/0.94
Soybeans (Preplant burndown)	0.5 or 1.0/1.0	0.46/0.47
Strawberries (Except CA or FL)	1.5/1.5	1.2/1.3
Sugarcane	2.0/4.0	0.75/0.99
Cereal Grains (Wheat, Barley, Millet, Oats and Rye)	0.5 or 1.25/1.75	Wheat= 0.44/0.48 Barley =0.46/0.47 Oats = 0.46/0.46 Rye = 0.50/0.50 Millet= 0.44/0.44
Wild Rice (MN only)	0.25/0.25	0.20/0.20

Other Sources of Use Information

The Phenoxy Herbicide NAPIAP report (Burnside et. al. 1996) has a great deal of information regarding the use of 2,4-D on a wide variety of crops. Selected information that is relevant for 2,4-D occupational exposure assessment is summarized in Table 8.

The USDA Forest Service 2,4-D Risk Assessment (USFS, 1998) has useful information about 2,4-D applications in forests and rights of way areas. This information is summarized below:

- The most commonly used ground application method is backpack (selective) foliar applications and a worker can treat approximately 0.5 acre per hour.
- Hack and squirt applications are used to eliminate large trees during site preparation, conifer release or rights of way maintenance. The worker usually treats 0.5 acres per hour.
- Boom spray or roadside hydraulic spraying is used primarily for roadside rights of way management. Usually 8 acres are treated in a 45 minute period with 200 gallons of spray solution, however, some special truck mounted spray systems may be used to treat 12 acres in a 35 minute period with 300 gallons.
- Aerial application is currently not used by the Forest Service.
- The typical application rate is 1.0 lb ae/acre with a range of 0.5 to 2.0 lbs ae/acre.

Table 8 - 2,4-D Use Information in the Phenoxy Herbicide NAPIAP Report	
Use Site	**NIPIAP Findings**
Aquatic Weed Control	2,4-D accounted for 56% of aquatic acreage treated. 97789 acres were treated for water hyacinth and 4652 acres were treated for Eurasian water milfoil by state agencies in 1993. 2,4-D provides control for at least one season. Liquid formulations are primarily used for hyacinth while granular formulations are primarily used for milfoil. State agencies want to use liquid formulations for milfoil because this would significantly reduce costs.
Asparagus	Used on 27% of the crop. Only use amine. Broadcast applied before spears emerge in the spring or between cuttings. Directed spray is applied after harvest with drop nozzles to keep 2,4-D off of ferns.
Citrus	IPE form is applied as a growth regulator to delay harvest.
Conifer Release	Most herbicides are applied by helicopter in western regions. In the south, skidder mounted broadcast systems with boomless nozzles are also in extensive use. The typical application rate is 2.0 lbs ae per acre.
Conifer Plantations	Many growers selective spray with 2,4-D in backpack sprayers in June.
Corn (field)	Preharvest applications are not commonly made because the weeds are too large, yield reduction has already occurred, crop is too tall for ground application and drift may occur from aerial application.
Corn (sweet)	Similar to field corn though sweet corn is more sensitive and drop nozzles are used. Normally only one application is made per season.
Fallow land	Approximately 20% of the 72 million acres in fallow was treated once with 2,4-D at a rate of 0.5 lb ae/acre. 70% of fallow acreage in Kansas was treated with 2,4-D.
Grain Sorgum	Major use is post emergence control of broadleaf weeds.
Grapes	2,4-D is important for the control of annual broadleaf weeds.
Orchard Floors	Used for selective control of broadleaf weeds in a grass cover.
Rice	18.5% of crop treated nationally with 45% crop treated in Louisiana. One treatment per year.
Rights of Way	Most products are applied by truck mounted sprayers and spray trains. Treatments are applied by backpack for ornamental plantings and around facilities such as pump stations. Generally applied in the spring but also applied in the fall in the south. Rates range from 1 to 2 lb/A.
Soybeans	Is used to control existing vegetation prior to planting no-till soybeans.
Strawberries	In the northeastern states where straw berries are a perennial crop, 70-90% of the acreage is treated with 2,4-D after harvest. Use is insignificant in CA because of methyl bromide fumigation.
Sugarcane	In some states multiple applications are made.
Small Grains	Use of 2,4-D is greater on spring wheat than on winter wheat because winter wheat is higher yielding and more competitive against weeds.
Wild Rice (MN only)	About 10% of crop is treated at a rate of 0.25 lb ae/acre.

Application Methods

The 2,4-D labels allow ground and aerial application, however, they do not allow chemigation. Ground applications are made whenever possible due to cost and convenience while aerial applications are made primarily to rice fields that are flooded or rangeland areas where woody weeds are too tall for a tractor (2,4-D Smart Meeting, 2001). Wiper bar applications can be made to crops such as blueberries and cranberries. Aquatic weeds can treated from boats either by foliar applications to floating weeds or by subsurface application of liquids or granular materials to submersed weeds. Forestry applications can be made by rotary winged aircraft (i.e. helicopters) for large scale conifer release programs or by backpack for smaller areas such as christmas tree plantations. Forestry applications can also be made to unwanted trees by injection or frill treatment.

2.0 Occupational and Residential Exposures and Risks

As discussed above, 2,4-D is used both in the agricultural and residential environment. The risks of mixing, loading and applying 2,4-D in the agricultural environment are discussed in section 2.1. Occupational post application exposures and risks are discussed in section 2.2. Residential applicator exposures and risk are discussed in section 2.3 and residential turf post application exposures and risks are discussed in section 2.4. Recreational swimmer post application exposure and risks are discussed in section 2.5.

2.1 Occupational Handler/Applicator Exposures & Risks

2.1.1 Exposure Scenarios

The following exposure scenarios were assessed based upon the application methods listed in Table 9.

Mixer/Loader

Mix/Load Wettable Powder
Mix/Load Liquid Formulations
Load Granules

Applicator

Aerial Application
Groundboom Application
Subsurface Application of Liquids to Submersed Aquatic Weeds
Airblast Application
Backpack Application
Rights of Way (ROW) Application
Foliar Application of Liquids to Floating Aquatic Weeds
Turfgun Application
Broadcast Spreader Application

Mixer/Loader/Applicator

Mix/Load/Apply Wettable Powder with a Turfgun
Mix/Load/Apply Liquids with a Turfgun
Mix/Load/Apply Water Dispersable Granules with a Turfgun
Mix/Load/Apply Liquids with a Backpack Sprayer
Load/Apply Granules with a Push Spreader

Flagger
Flag Aerial Application

2.1.2 Exposure Assumptions and Data Sources

The following assumptions and factors were used in order to complete the exposure and risk assessments for occupational handlers/applicators:

- The average work day was 8 hours.
- A listing of application methods and amounts of acreage treated per 8 hour day is included in Table 9.
- The application rate for submerged aquatic weeds is based upon the master label rate of 10.8 lbs a.i. per acre foot times an average lake depth of 5 feet.
- Maximum application rates and daily acreage were used to evaluate short term exposures.
- Average application rates were used to evaluate intermediate term exposures.
- A body weight of 60 kg was assumed for short term exposures because the short term endpoint relates to females 13-50 years of age.
- A body weight of 70 kg was assumed for intermediate term exposures because the intermediate term endpoint is not gender specific.
- The dermal absorption rate is 5.8%.
- The inhalation absorption rate is 100%.
- Baseline PPE includes long sleeve shirts, long pants and no gloves or respirator.
- Single Layer PPE includes baseline PPE with gloves.
- Double Layer PPE includes coveralls over single layer PPE
- Double Layer PPE PF5 includes above with a PF5 respirator (i.e. a dustmask)
- Double Layer PPE PF10 includes above with a PF10 cartridge respirator
- Only closed cockpit airplanes are used for aerial application.
- There are very little exposure data to evaluate the exposure in rotary winged aircraft, therefore, the exposure data for fixed wing aircraft are used as a surrogate.
- Airplane and helicopter pilots do not wear chemical resistant gloves.

Table 9 - 2,4-D Application Methods		
Application Method	**Typical Crops Treated**	**Treated Area**[a]
Aerial	Small Grain, Field Corn, Sugarcane Citrus Growth Regulation	1200 350
Groundboom	Small Grains, Field Corn, Sugarcane Orchard/Vineyard Floors Strawberries	200 80 80
Subsurface Application of Liquids	Submersed Aquatic Weeds	30[b]
Airblast	Citrus Growth Regulation	40
Backpack Sprayer - Mix/Load/Apply	Christmas Tree Plantations	2[c]
Backpack Sprayer - Apply Only	Conifer Release	4[d]
Right of Way (ROW) Sprayer	Weed Control - 20 gallons per acre Brush Control - 400 gallons per acre	50[e] 2.5[e]
Foliar Application of Liquids	Floating Aquatic Weeds	10[f]
Broadcast Spreader - Tractor Drawn or Boat Mounted	Turf Submersed Aquatic Weeds	40 50[g]
Turfgun	Turf	5
Broadcast Spreader - Push Type	Turf	5

Notes

a. Except as noted, the acres treated per day values are from ExpoSAC Policy #9 “Standard Values for Daily Acres Treated in Agriculture”, Revised 7/5/2000.

b. The area treated for aquatic application of liquids to submersed aquatic weeds is based information provided in an email of 12/11/03 from Dr. Kurt Getsinger of the US Army Corps of Engineers to Timothy C. Dole of the US EPA Office of Pesticide Programs.

c. The area treated for Backpack Sprayer (Mix/Load/Apply) is 40 gallons per day from ExpoSAC Policy #9 divided by the label recommended spray volume of 20 gallons per acre.

d. The area treated for Backpack Sprayer (Apply Only) is 4 acres per day based upon the acreage treated in CA DPR HS-1769 normalized to an 8 hour day.

e. The area treated for ROW sprayers was determined by the dividing the daily spray volume handled (1000 gallons per day) from ExpoSAC Policy #9 by the label recommended spray volume of 20 gallons per acre for weed control and 400 gallons per acre for woody brush control.

f. The area treated for foliar application of liquids to floating aquatic weeds is based upon use information reported in the HED Memorandum “Occupational and Residential Exposure Characterization/Risk Assessment for Triclopyr Triethylamine for Aquatic Weed Control, DP Barcode D269448 of 7/22/2002.

g. The area treated for application of granules to submersed aquatic weeds is based upon information provided in an email of 11/22/2000 from Jim Kannenburg of Marine Biochemists/Applied Biochemists to Troy Swackhammer of the US EPA Office of Pesticide Programs.

Handler Exposure Data Sources

The handler exposure data were taken from the Pesticide Handler Exposure Database (PHED), the Outdoor Residential Exposure Task Force (ORETF) and the California Department of Pesticide Regulation (CA DPR). The PHED data were used primarily for the large scale agricultural and forestry scenarios and the ORETF data were used for lawn care scenarios. The CA DPR data were used for the backpack applicator forestry scenario where multiple applicators are supplied by a nurse tank. A summary of each data source is provided below.

PHED Data

PHED was designed by a task force of representatives from the US EPA, Health Canada, the California Department of Pesticide Regulation, and member companies of the American Crop Protection Association. PHED is a software system consisting of two parts – a database of measured exposure values for workers involved in the handling of pesticides under actual field conditions and a set of computer algorithms used to subset and statistically summarize the selected data. Currently, the database contains values for over 1,700 monitored individuals (i.e., replicates). The distribution of exposure values for each body part (e.g., chest, upper arm) is categorized as normal, lognormal, or "other" (i.e., neither normal nor lognormal). A central tendency value is then selected from the distribution of the exposure values for each body part. These values are the arithmetic mean for normal distributions, the geometric mean for lognormal distributions, and the median for all "other" distributions. Once selected, the central tendency values for each body part are composited into a "best fit" exposure value representing the entire body.

The unit exposure values calculated by PHED generally range from the geometric mean to the median of the selected data set. To add consistency and quality control to the values produced from this system, the PHED Task Force has evaluated all data within the system and has developed a set of grading criteria to characterize the quality of the original study data. The assessment of data quality is based upon the number of observations and the available quality control data. These evaluation criteria and the caveats specific to each exposure scenario are summarized in Table B1 of Appendix B. While data from PHED provide the best available information on handler exposures, it should be noted that some aspects of the included studies (e.g., duration, acres treated, pounds of active ingredient handled) may not accurately represent labeled uses in all cases. HED has developed a series of tables of standard unit exposures for many occupational scenarios that can be used to ensure consistency in exposure assessments.

Unit exposure values were calculated in PHED using the following protection factors for PPE: second layer of clothing = 50% PF for dermal exposure to the body, chemically resistant gloves 90% PF for dermal exposure to the hands, dust mask 80% PF for inhalation exposure and half face cartridge respirator = 90% PF for inhalation. Engineering controls are assigned a protection factor of 90% to 98% depending upon the type of engineering controls selected.

ORETF Data

Handler exposure data generated by the Outdoor Residential Exposure Task Force (ORETF) were used for assessing the lawn care operator scenarios. These studies are summarized in the HED Memorandum "Summary of HED's Reviews of ORETF Chemical Handler Exposure Studies; MRID 449722-01", DP Barcode D261948 of April 30, 2001. These studies used Dacthal as a surrogate compound with a target application rate of 2.0 lbs/ae acre. These studies were conducted in accordance with current Agency guidelines and the data generated were of high quality. These studies have been reviewed by HED and Health Canada.

California Department of Pesticide Regulation Exposure Data

The study HS-1769 "Exposure of Hand Applicators to Triclopyr in Forest Settings, 1995 " was used to assess the exposure of backpack application for conifer release. This study was conducted by the California Environmental Protection Agency, Department of Pesticide Regulation, Worker Health and Safety Branch.

Ten applicators were monitored for two days for a total of 20 replicates as they applied Garlon using Solo Backpack Sprayers which were filled from a 300 gallon mixing tank. The workers treated an average of 3.2 acres during each 9 hour day with a spray volume of 25 gallons per acre and an application rate of 1.0 lb triclopyr ae per acre. The actual spraying time was 360 minutes per day with the remainder of time spent placing plastic bags over the seedlings at the start of the workday, removing the bags at the end of the day, pulling hose, lunch/rest breaks and donning monitoring clothing and equipment.

Dermal exposures were monitored using long sleeve t-shirt and knee length socks, hand and face/neck exposures were monitored using Chubbs baby wipes and inhalation exposures were monitored using glass fiber filters. The workers typically wore coveralls over the dosimeters. The results of the socks were extrapolated to rest of the leg by the Agency using a factor of 2.04 to account for the thighs. This factor is based upon the surface area of the thighs, lower legs and feet (7510 cm^2) divided by the surface area of the lower legs and feet (3690 cm^2).

The field recovery was 60 $\pm$ 21% for the air filters at 100 ug/sample, 95.9 $\pm$ 8.7% for the wipes at 100 ug/sample, 85.6 $\pm$ 8.0% for the sock dosimeters at 100 ug/sample and 98.2 $\pm$ 5.1% at 5000 ug/sample for the t-shirt dosimeters. The measured results were above the fortification levels for the dermal media and were approximately one tenth the fortification level for the air filters. The minimum storage stability sample recoveries were 81 $\pm$ 40% for the air filters at week 31, 88% $\pm$ 7.3% for the socks at week 16, 93.2 $\pm$ 2.4% for the T-shirt at week 10 and 93.2 $\pm$ 6.5% for the wipes at week 16. Method validation data were also provided and substantiated the LOQs of 150 ug/sample for the T-shirts, 40.1 ug/sample for the socks, 10 ug/sample for the wipes and 1.5 ug/sample for the air filters. All of the results were above the LOQs.

This study meets Agency guidelines and is acceptable for use in risk assessment. The major limitation is the use of knee length socks to estimate exposures to the thighs. This could be significant because the majority of the exposure (53%) was measured on the legs, while lessor amounts were measured on the torso (33%), hands (13%) and head/face (2.3%). In a backpack applicator study on grasslands in England, however, 86% of the leg exposure occurred to the lower legs, 11% occurred on the thighs and 3.5% occurred on the feet (Abbot et. al. 1983) . This study was conducted with whole body dosimeters. Another limitation is that 4 of the 20 inhalation replicates were not valid because the sampling pump flowrate decreased by more than 25 percent by the end of the sampling period. The data from this study are summarized in Table 10. In accordance with ExpoSAC Policy the geometric mean values will be used as the appropriate measure of central tendency for exposure assessment because the data have a lognormal distribution.

Table 10 - Unit Exposure Values for Backpack Application in Forest Settings (CA DPR HS-1769)

Unit Exposures per lb ae handled	N	Mean	SD	Geo. Mean[1]	Median	90th Percentile	Maximum	W-test Result for Normality
Dermal (mg/lb ae)	20	8.1	7.1	**6.1**	6.9	15.1	30.9	Lognormal
Inhalation (ug/lb ae)	16	56	17	**54**	56	78	91.1	Lognormal

Note 1 - The values in bold font are used for risk assessment in accordance with ExpoSAC Policy.

2.1.3 Exposure and Risk Estimates

Calculation Methodology and Equations

Daily dermal and inhalation exposures, absorbed doses and MOEs are calculated as described in Appendix A. The basic rationale for these calculations is that the daily exposure is the product of the amount of ai handled per day times a unit exposure value. The target MOEs are 100 for both short and intermediate term exposures. Scenarios with MOEs greater than the target MOEs are not of concern for the occupational population.

Results and Comparison to Target MOE

The MOEs for Handlers are summarized in Tables 11 and 12 and a detailed listing of these MOEs is also included in Appendix B. With the exception of mixing/loading wettable powder, most of the MOEs exceed the target of 100 with baseline or single layer PPE and are not of concern. The MOEs for handling wettable powder are acceptable with engineering controls (i.e. water soluble bags). The labels typically require single layer PPE for applicators and handlers and that a mechanical transfer system (probe and pump or spigot) be used for transferring the contents of containers of 5 gallons or more. The mechanical transfer system is not required for >1 to <5 gallon containers, however, additional PPE (coveralls or a chemical resistant apron) are required if the mechanical transfer system is not used. Most of the wettable powder products are packaged in water soluble bags.

Table 11 - Summary of 2,4-D Short Term MOEs for Occupational Handlers

Exposure Scenario	Crop Type	Application Rate (lb ae/acre)	Acres/ Day	Base-line	Single Layer	Single Layer PF5	Single Layer PF10	Double Layer PF10	Eng. Control
Mixer/Loader (M/L)									
M/L WP	All Crops	0.25 to 4	5 to 1200	**≥1.4**	**≥6**	**≥17**	**≥22**	**≥26**	≥390
M/L Liquids	All Crops	0.25 to 4	5 to 1200	**≥1.8**	≥130	≥200	≥220	≥270	≥550
M/L Liquids	Submersed Weeds	54	30	**5.5**	370	580	630	820	1600
Load Granulars for Broadcast Spreader	Golf Courses and Aquatic Areas	2 to 54	40 or 50	>1000	>1000	>1000	>1000	>1000	>1000
Applicator (APP)									
Aerial Application	All Crops	1.25 to 4.0	1200	ND	ND	ND	ND	ND	>850
Groundboom Application	All Crops	1.25 to 4	40 to 200	>1000	>1000	>1000	>1000	>1000	>1000
Subsurface Aquatic Application of Liquids	Submersed Weeds	54	30	600	600	970	1050	1300	2800
Airblast Application	Citrus	0.1	40	>1000	>1000	>1000	>1000	>1000	>1000
Backpack Application	Conifer Release	4	4	ND	230	260	260	ND	ND
ROW Application	Weed Control	2	50	190	570	640	650	870	ND
Foliar Aquatic Application of Liquids	Floating Weeds	2	10	950	>1000	>1000	>1000	>1000	>1000
Turfgun Application	turf	2	5	ND	>1000	>1000	>1000	>1000	>1000
Broadcast Spreader Application	Golf Courses and Aquatic Areas	2 or 54	40 or 50	>1000	>1000	>1000	>1000	>1000	>1000
Mixer/Loader/Applicator (M/L/A)									
M/L/A Liquids with Backpack Sprayer	Christmas Trees	4	2	ND	>1000	>1000	>1000	>1000	ND
M/L/A WD Granules with a Turfgun	turf	2	5	ND	>1000	>1000	>1000	>1000	ND
M/L/A Wettable Powder with a Turf Gun	turf	2	5	ND	>1000	>1000	>1000	>1000	>1000
M/L/A Liquid Flowables with a Turfgun	turf	2	5	ND	>1000	>1000	>1000	>1000	ND
Load/Apply Granules with a Push Spreader	turf	2	5	ND	>1000	>1000	>1000	>1000	ND
Flagger									
Flag Aerial Liquid Application	All Crops	1.25 to 4.0	1200	≥320	≥300	≥410	≥430	≥470	≥16000

MOEs in bold font do not exceed the target MOE of 100 and are of concern

Table 12 - Summary of 2,4-D Intermediate Term MOEs for Occupational Handlers

Exposure Scenario	Crop Type	Application Rate (lb ae/acre)	Acres/ Day	Base-line	Single Layer	Single Layer PF5	Single Layer PF10	Double Layer PF10	Eng. Control
Mixer/Loader (M/L)									
M/L WP	All Crops	0.25 to 4	5 to 1200	**≥1.7**	**≥8.3**	**≥24**	**≥31**	**≥37**	≥540
M/L Liquids	All Crops	0.25 to 4	5 to 1200	**≥2.6**	≥170	≥280	≥300	≥390	≥750
M/L Liquids	Submersed Weeds	54	30	**3.8**	250	420	450	570	1100
Load Granulars for Broadcast Spreader	Golf Courses or Aquatic Areas	2 or 54	40 or 50	≥180	≥190	≥530	≥680	>1000	>1000
Applicator (APP)									
Aerial Application	All Crops	0.5 to 2.0	1200	ND	ND	ND	ND	ND	>1200
Groundboom Application	All Crops	0.5 to 4	40 to 200	>1000	>1000	>1000	>1000	>1000	>1000
Subsurface Aquatic Application	Submersed Weeds	54	30	420	420	680	730	920	2000
Airblast Application	Citrus	0.1	40	>1000	>1000	>1000	>1000	>1000	>1000
Backpack Application	Conifer Release	2	4	ND	320	360	370	ND	ND
ROW Application	Weed Control	2	50	130	390	450	460	610	ND
Foliar Aquatic Application of Liquids	Floating Weeds and Wild Rice	4 or 0.25	10	≥330	≥990	>1000	>1000	>1000	>1000
Turfgun Application	turf	2	5	ND	>1000	>1000	>1000	>1000	>1000
Broadcast Spreader Application	Golf Courses and Aquatic Areas	2 or 54	40 or 50	≥220	≥240	≥590	≥720	>1000	>1000
Mixer/Loader/Applicator (M/L/A)									
M/L/A Liquids with Backpack Sprayer	Conifer Plantations	4	2	ND	720	860	880	1400	ND
M/L/A WD Granules with a Turfgun	turf	2	5	ND	>1000	>1000	>1000	>1000	ND
M/L/A Wettable Powder with a Turf Gun	turf	2	5	ND	>1000	>1000	>1000	>1000	>1000
M/L/A Liquid Flowables with a Turfgun	turf	2	5	ND	>1000	>1000	>1000	>1000	ND
Load/Apply Granules with a Push Spreader	turf	2	5	ND	>1000	>1000	>1000	>1000	ND
Flagger									
Flag Aerial Liquid Application	All Crops	0.50 to 2.0	1200	≥910	≥860	≥1200	≥1300	≥1400	≥32000
MOEs in bold font do not exceed the target MOE of 100 and are of concern									

2.1.4 Risk Characterization

Only a few 2,4-D products are formulated as wettable powders and most of these products are packaged in water soluble bags. These products are labeled primarily for use on turf.

2.2 Occupational Post Application Exposure and Risks

Post application 2,4-D exposures can occur in the agricultural environment when workers enter fields recently treated with 2,4-D to conduct tasks such as scouting and irrigation.

2.2.1 Post Application Exposure Scenarios

2,4-D, which is highly selective for broadleaf weeds, can cause leaf damage to some of the labeled broadleaf crops and the labels specify that it should be applied to the ground in such a manner as to minimize foliar residues and crop damage. This is particularly true for crops such as berries, grapes and tree fruits. To provide weed control without damaging the crops, applications are made during the dormant season or prior to planting, sprays are directed to the rows/middles or orchard floors and drop booms and/or shields are used to prevent crop foliar contact. These techniques also prevent post application exposures because they minimize the amount of residue on the crop foliar surfaces. Broadcast applications can be made to grass crops such cereal grains, rice and sugarcane which are tolerant of 2,4-D.

Given the above characteristics of 2,4-D, it is anticipated that post application exposures would primarily occur following treatment of the grass crops. Because 2,4-D is typically applied only once per season and because the application window for a particular crop is typically one month per year, it is anticipated that 2,4-D exposures would primarily be short term. In rare instances where two crops treated with 2,4-D are grown in proximity allowing multiple applications, there may be the possibility of intermediate term exposure.

Potential inhalation exposures are not anticipated for the post-application worker scenarios because of the low vapor pressure of 2,4-D (2.0e-07 torr at 20^{o} C).

In the Worker Protection Standard (WPS) a restricted entry interval (REI) is defined as the duration of time which must elapse before residues decline to a level so entry into a previously treated area and engaging in a specific task or activity would not result in exposures which are of concern. The WPS Restricted Entry Interval (REI) for 2,4-D is 12 hours for the ester and sodium salt forms and is 48 hours for the acid and amine salt forms.

2.2.2 - Exposure Data Sources, Assumptions and Transfer Coefficients

<u>Data Sources:</u>

There are three turf transferable residue studies that were submitted by the Broadleaf Turf Herbicide TTR Task Force. The field portion of the studies were conducted by Grayson Research LLC of Creedmore, North Carolina, AGSTAT of Verona, Wisconsin, and Research for Hire of Porterville California. The laboratory analysis for all three studies was conducted by Covance Laboratories of Madison, Wisconsin. These studies measured the dissipation of several phenoxy herbicides, including 2,4-D, using the OREFT roller technique (which is also called the modified California Roller). The studies have been reviewed by HED and were found to meet all of the series 875 guidelines for postapplication exposure monitoring. The studies are summarized on the following pages.

Determination of Transferable Turf Residues on Turf Treated with 2,4-D, 2,4-D-p, MCPA, MCPP-p and Dicamba, MRID 446557-01(Phase 1 - Effect of Form)

The purpose of this study was to assess the effects of different forms of phenoxy herbicides including 2,4-D upon the day zero turf transferable residues (TTR) and dissipation rates. In two cases 2,4-D was applied by itself while in one case it was applied as a tank mixture with the other herbicides. All of the applications were made to cool season fescue turf plots in North Carolina using a ground-boom sprayer. The plots were mowed to a height of two inches prior to the application and were not mowed again until after the seventh day of sampling. No irrigation was performed. Significant rainfall (i.e. greater than 0.05 inches) did not occur until DAT 10 when 0.17 inches occurred prior to the DAT 10 sample.

Sampling was conducted with a ORETF roller using a 27" X 39" percale cotton cloth in accordance with the SOP developed by the ORETF. Samples were collected after the sprays had dried and at 0.5, 1, 2, 3, 4, 5, 6, 7, 10 and 14 days after treatment (DAT). The samples were analyzed using Method 1 as described and validated in MRID 446557-04 and the LOQ was 0.879 ng/cm^2. The concurrent laboratory recoveries were 108 $\pm$ 11.3 (n=8) for 2,4-D 2-EHE and 108 $\pm$ 15.4 (n=15) for 2,4-D DMA. These recoveries did not vary significantly with respect to the fortification levels which ranged from 1 to 900X LOQ. Field recovery samples were prepared at DAT 0 and DAT 6 using fortification levels of 0.004 and 0.04 ug/cm^2. The recoveries for 2,4-D EHE were 110 $\pm$ 8.4 (n=12) and did not vary with respect to fortification level or day of preparation. The recovery for 2,4-D DMA was 99.1 $\pm$ 7.7 (n=6) and did not vary with respect to fortification level. Only the DAT 0 samples were used for 2,4-D DMA, however, because the evaporation of the extraction solvent caused high recoveries on the DAT 6 samples. The raw data were not corrected for field recovery because the recoveries were greater than 90 percent.

A summary of the results are shown in Table 13 and a more detailed listing is included in Appendix F. The highest TTR levels occurred on DAT 1 for the single ingredient application and were greater for the DMA form of 2,4-D. The highest TTR level for 2,4-D DMA applied as part of a combination occurred on DAT 0.5. The TTR levels declined to the LOQ in 10 days for the EHE treatment, 7 days for the DMA treatment and 5 days for the DMA combination treatment.

Table 13 - Dissipation of 2,4-D Applied to Turf Using Various Forms (Phase 1)					
2,4-D Form	**Application Rate (lb ae/acre)**	**Maximum TTR[2] (ug/cm^2)**	**Percent Applied as TTR**	**Correlation Coefficient**	**Half Life (days)**
EHE	1.7	0.34 $\pm$ 0.87 (n=3)	1.8	0.96 (n=30)	1.2
DMA	1.7	0.56 $\pm$ 0.20 (n=3)	2.9	0.90 (n=27)	0.83
DMA Comb[1]	1.6	0.31 $\pm$ 0.066(n=3)	1.7	0.91 (n=21)	0.53

1. The combination included 2,4-D DMA, MCPP-p and dicamba.
2. The maximum TTR occurred on DAT 1 for EHE and DMA. The maximum TTR for the DMA combination occurred on DAT 0.5.

Determination of Transferable Turf Residues on Turf Treated with 2,4-D DMA + MCPP-p DMA + Dicamba DMA in Various Spray Volumes, - MRID 446557-03
(Phase 2 - Effect of Spray Volume)

The purpose of this study was to assess the effects of different spray volumes upon the day zero TTRs and dissipation rates of phenoxy herbicides. In all cases 2,4-D was applied in combination with MCPP-p DMA and dicamba DMA All of the applications were made to cool season fescue/blue grass turf plots in North Carolina using a ground-boom sprayer. The plots were mowed to a height of two inches prior to the application and were not mowed again until after the seventh day of sampling.

No irrigation was performed. No rain occurred on DAT 0 or DAT 1 and 0.17 inches of rain occurred prior to the DAT 2 sample, 0.46 inches occurred prior to the DAT 3 sample and 0.03 inches occurred prior to the DAT 4 and 5 samples.

Sampling was conducted in the same manner as for Phase 1 using an ORETF roller with cotton cloth. Samples were collected at 3 and12 hours after treatment (HAT) and at 1, 2, 3, 4, 5, 6, 7, 10 and 14 DAT. The samples were analyzed using Method 2 as described and validated in MRID 446557-04 and the LOQ was 0.879 ng/cm^2. The concurrent laboratory recovery was 82.8 $\pm$ 11.5 (n=28) and did not vary significantly with respect to the fortification levels which ranged from 1 to 400X LOQ. Field recovery samples were prepared at DAT 0 and DAT 6 using fortification levels of 0.004 and 0.04 ug/cm^2. The recoveries were 89.7 $\pm$ 7.2 (n=6) at 0.004 ug/cm^2 and 78.8 $\pm$ 5.9 (n=6) at 0.040 ug/cm^2. When considered by DAT, the recoveries were 82.0 $\pm$ 5.8 (n=6) for the DAT 0 samples and 86.5 $\pm$ 10.6 (n=6) for the DAT 6 samples. The raw data were corrected for field recovery by using 0.788 for data greater than 0.040 ug/cm^2 and 0.897 for data less than 0.040 ug/cm^2.

A summary of the results are shown in Table 14 and a more detailed listing is included in Appendix F. The half lives ranged from 0.29 to 0.32 days and were calculated based upon the first three days of dissipation because the TTRs reached the LOQ by DAT 3.

Table 14 - Dissipation of 2,4-D Applied to Turf at Various Spray Volumes (Phase 2)					
Spray Volume (GA/acre)	**Application Rate (lb ae/acre)**	**Maximum TTR[1] (ug/cm^2)**	**Percent Applied as TTR**	**Correlation Coefficient**	**Half Life (days)**
2	1.76	0.23 $\pm$ 0.035 (n=3)	1.0	0.79 (n=15)	0.31
5	1.76	0.25 $\pm$ 0.064 (n=3)	1.3	0.90 (n=15)	0.29
20	1.76	0.17 $\pm$ 0.025 (n=3)	0.87	0.95 (n=15)	0.32
1. The maximum average TTR occurred on DAT 1.0, DAT 0.0 and DAT 0.5 for the 2, 5 and 20 GPA applications, respectively.					

Determination of Transferable Turf Residues on Turf Treated with 2,4-D DMA, MCPA DMA, 2,4-D DMA + MCPP-p DMA + Dicamba DMA and MCPA DMA + MCPP-p DMA + 2,4-DP-p-DMA - MRID 450331-01 (Two Additional Sites)

The purpose of this study was to assess the effects of two additional sites upon the day zero TTRs and dissipation rates of phenoxy herbicides. The 2,4-D DMA was applied either by itself (Treatment 2) or in combination with MCPP-p DMA and dicamba DMA (Treatment 4). The applications were made to Kentucky Bluegrass turf plots in Wisconsin and to Dwarf Fescue turf plots in California using ground-boom sprayers with a spray volume of 9.4 to 9.9 gallons per acre. The plots were mowed to a height of two inches prior to the application and were not mowed again until after the seventh day of sampling. No irrigation was performed. No rain occurred at the California site, however, the grass was wet with dew during the DAT 0.5 sampling which occurred at night. The following rainfall occurred at the Wisconsin site: 0.025 inches prior to the HAT 8 sample, 0.145 inches prior to the HAT 12 sample and 0.19 inches prior to the HAT 24 sample.

Sampling was conducted in the same manner as for Phases 1 and 2 using the ORETF roller with cotton cloth. Samples were collected at 1, 4, 8, 12 and 24 HAT and 2, 3, 4 and 7 DAT. The samples were analyzed using Method 2 as described and validated in MRID 446557-04 and the LOQ was 0.879 ng/cm^2. The concurrent laboratory recovery for the California site data was 104 $\pm$ 11.5 percent (n=17) and did not vary significantly with respect to the fortification levels which ranged from 1 to 1600X LOQ. The concurrent laboratory recovery for the Wisconsin site data was 87.1 $\pm$ 12.7 percent (n=17) and did not vary significantly with respect to the fortification levels which ranged from 1 to 600X LOQ. Field recovery samples were prepared in the same manner as for Phases 1 and 2 with the exception that a different fortification solution was used. In Phases 1 and 2, the fortification solution contained only acetone as the solvent, while in this study 0.1 M phosphoric acid was added to the acetone. The recoveries obtained were very low and were not reported. These low recoveries were thought to be the result of interference caused by the acid interaction with the cotton during storage.

A summary of the results are shown in Table 15 and a more detailed listing is included in Appendix F. The TTR values declined to the LOQ by DAT 1 in Wisconsin and to 40X LOQ by DAT 7 in California. The California TTRs declined steeply during DAT 1 and at a much slower rate during DAT 1 through 7. The data for DAT 0.5 at the California site are not included because these samples were collected at night when there was dew.

Table 15 - Dissipation of 2,4-D Applied to Turf at Sites in California and Wisconsin					
Site - Treatment[1]	**Application Rate (lb ae/acre)**	**Maximum TTR[2] (ug/cm^2)**	**Percent Applied as TTR**	**Correlation Coefficient**	**Half Life (days)**
CA-2	1.67	0.24 $\pm$ 0.030 (n=3)	1.3	0.78 (n=24)	2.8
CA-4	1.66	0.20 $\pm$ 0.020 (n=3)	1.1	0.91(n=24)	2.6
WI-2	1.65	0.21 $\pm$ 0.031 (n=3)	1.1	0.92 (n=15)	0.12
WI-4	1.64	0.21 $\pm$ 0.021(n=3)	1.1	0.89 (n=15)	0.11

1. Treatment 2 consisted of 2,4-D by itself. Treatment 4 consisted of 2,4-D with MCPP-p and dicamba
2. The maximum TTR occurred on HAT 1 for the both CA sites, on HAT 1 for the WI-2 and on HAT 8 for the WI-4 site.

Overall Summary and Application of the TTR Data

A detailed listing of the TTR data is included in Appendix F and a summary of the data used for occupational exposure assessment is included in Table 16. The maximum TTR values of 2.9% of the application rate in North Carolina and 1.3% of the application rate in California were used for assessing exposures in humid and dry regions, respectively. The Wisconsin data were not used because the rain occurred on DAT 1 which caused the TTRs to decline to the LOQ by the end of DAT 1. The dissipation rates were not used because the MOEs on day zero were greater than 100.

Table 16 - Summary of TTR Data Used for Occupational Post Application Exposure Assessment			
	NC - Phase 1	**NC - Phase 2**	**CA**
Conditions	No Rain	Some Rain After DAT 2	No Rain
Application Rate (lbs ae/acre)	1.72	1.76	1.67
Maximum TTR (ug/cm^2)	0.56	0.25	0.24
Maximum TTR (percent of applied)	2.9 - Note 1	1.3	1.3

Assumptions

The following assumptions were made regarding occupational post application:

- Short term risks were assessed using master label rates.
- Intermediate term risks were assessed using average application rates when available.
- The transfer coefficients as listed in Table 17 are from an interim transfer coefficient policy developed by HED's Science Advisory Council for Exposure using proprietary data from the Agricultural Re-entry Task Force (ARTF) database (US EPA, August 7, 2001). This policy will be periodically updated to incorporate additional information about agricultural practices in crops and new data on transfer coefficients. Much of this information will originate from exposure studies currently being conducted by the ARTF, from further analysis of studies already submitted to the Agency, and from studies in the published scientific literature.
- The transfer coefficients for turf harvesting and maintenance are based upon recently conducted ARTF studies that are being reviewed by HED.
- In cases where applications would be made in such a way as to minimize contact with crop foliage post application exposures are expected to be negligible and are not assessed. These cases are included in Table 17.
- The initial percent of application rate as Dislodgeable Foliar Residue (DFR) was assumed to be 20% for all crops except turf. This is the standard value used in the absence of chemical specific data.

Calculation Methodology for Post Application Exposures

The calculations used to estimate the exposures for the post-application scenarios are similar to those described previously for the handler/applicator scenarios and are described in Appendix A. Daily dermal exposure is calculated by multiplying the residue level (ug/cm^2 of leaf area) times a transfer coefficient (amount of leaf area contacted per unit time) time the duration worked (hr). Inhalation exposures were not calculated for the post-application scenarios because inhalation exposures have been shown to account for a negligible percentage of the overall body burden, particularly when the pesticide is applied outdoors and has a low vapor pressure. The vapor pressure of 2,4-D is 2.0e-07 torr at 20^o C.

Table 17 - Post Application Exposure Scenarios and Transfer Coefficients for 2,4-D		
Crop	**Label Directions** **Post Application Exposure Scenarios**	**Transfer Coefficient (cm^2/hr)**
Asparagus	Apply immediately after cutting before regrowth of new spears or post harvest. Spears contacted by the spray may be malformed and off flavor. Do not exceed two applications per crop. Do not apply within 30 days of previous application. Pre Harvest Interval (PHI) = 3 days	None[1,2]
Blueberries - High Bush	Make directed or shielded applications in the spring. Make directed applications to row middles in summer or fall after harvest.	None[1]
Blueberries - Low Bush	Make directed wipe or spot applications when weed tops are above crop. Make directed application to cut hardwoods in row middles in summer or fall after harvest. Avoid contact with blueberry foliage and apply only in the non-bearing year.	None[1]
Cereal Grains	Apply Post-emergence rate (1.25 lb ae/acre) after grain is fully tillered (4-8" high). Apply Pre-harvest rate (0.5 lb ae/acre) at the dough stage. PHI = 14 days Low Exposure Scenarios - Irrigation, scouting, immature plants Medium Exposure Scenarios - Same as above on mature plants	 100 1500
Citrus	Applied to trees to prevent fruit drop and increase fruit size. PHI = 7 days.	None[3]
Conifer Plantations	Apply over the top to firs prior to bud break or after complete bud set and hardening in the late summer or fall. Avoid treatment during the year of harvest. Directed sprays may be made to weeds in Christmas tree plantations of all conifer species, but the spray must not contact tree foliage as injury may occur.	None[1]
Corn, Field and Popcorn	Apply Preemergence rate (1.0) before corn emerges. Apply Post Emergence rate (0.5) when corn is less than 8" tall or by using drop nozzles. Apply Preharvest rate (1.5) after dough or at denting stage. Not applied in tassel to dent stage. PHI = 7 days. Low Exposure Scenarios - Scouting, weeding immature plants Medium Exposure Scenarios - Scouting, weeding more mature plants High Exposure Scenarios - Scouting, weeding, irrigation mature plants Very High Exposure Scenarios - Detasseling	 100 400 1000 NA[4]
Corn, Sweet	Apply Preemergence rate (1.0) before corn emerges. Apply Post Emergence rate (0.5) when corn is less than 8" tall or by using drop nozzles. Preharvest rate not used. PHI = 45 days. Low Exposure Scenarios - Scouting, immature plants	 100
Cranberries	Make broadcast applications at dormant rate (4.0) in the dormant season. Make directed wipe or spot applications at the postemergence rate (1.2) when weed tops are above crop. PHI = 30 days.	None[1]
Filberts	Spray on suckers that arise from the base of the trees.	None[1]
Grapes	Use hooded boom sprayer or equivalent to direct coarse spray to weeds and minimize potential contact with grape foliage, shoots or stems..	None[1]
Orchard Floors	For control of weeds on orchard floors. PHIs are 14 days for pome fruits, 40 days for stone fruits and 60 days for nuts.	None[1]
Pasture, Rangeland, Grassland	PHI = 7 days	None[1]
Potatoes	Make first application when potatoes are in the pre-bud stage (7 to 10" high) and second application is made 10 to 14 days later. PHI = 45 days.	None[3]
Rice, Wild	Applied to rice in the 1 to 2 aerial leaf through early tillering stage. Not applied after boot stage. PHI = 60 days.	See Below

Table 17 - Post Application Exposure Scenarios and Transfer Coefficients for 2,4-D		
Crop	**Label Directions** **Post Application Exposure Scenarios**	**Transfer Coefficient (cm^2/hr)**
Rice, Conventional	Apply Preplant rate (1.0) 2 to 4 weeks prior to planting. Apply Postemergence rate (1.5) at the late tillering stage usually 6 to 9 weeks after emergence. Do not apply after panicle initiation. PHI = 60 days. Low Exposure Scenarios - Irrigation, scouting, immature plants Medium Exposure Scenarios - Same as above on mature plants	 100 1500
Sorghum, Grain or Forage	Apply when sorghum is 6 to 15" tall. If sorghum is taller than 8" use drop nozzles and keep spray off the foliage. Low Exposure Scenarios - Scouting immature plants High Exposure Scenarios - Irrigation and scouting mature plants	 100 NA[5]
Soybeans	Apply for preplant burndown not less than 7 to 30 days prior to planting.	None[1]
Strawberries	Apply when strawberries have gone into dormancy or after last picking.	None[1]
Sugarcane	Apply before canes appear for control of emerged weeds. Apply after canes emerge and through canopy closure. Medium Exposure Scenarios - scouting immature plants High Exposure Scenarios - scouting mature plants	 1000 2000
Turf, Sod Farm and Golf Course	Treat when weeds are young and actively growing. Do not apply more than 4.0 lb per season. Low Exposure Scenarios - Mowing High Exposure Scenarios - Transplanting, hand weeding	 3400 6800
1. Post application exposures are expected to be minimal due to application timing or method. 2. Asparagus plants do not have foliage (i.e. ferns) when the spears are harvested. 3. The application rates are extremely low (0.1 lb ae/acre for citrus and 0.07 lb ae/acre for potatoes). 4. Detasselling TC does not apply to field corn because label prohibits application during tassel to dent stage. 5. This TC does not apply because 2,4-D is applied when the plants are immature.		

2.2.3 Exposure and Risk Estimates

A summary of the worker risks for short term post application exposures is given in Table 18 and the calculations are included in Appendix C. All of the short term MOEs are above 100 on day zero which indicates that the risks are not of concern. The intermediate term MOEs as shown in Table 19 and Appendix D are also all above 100 on day zero.

Table 18 - 2,4-D Postapplication Short Term Worker Risks				
Crop Group	**ShortTerm MOE on Day 0**			
	Application Rate (lb a.e./acre)	**Low Exposure Scenarios***	**Medium Exposure Scenarios***	**High Exposure Scenarios***
Field/row crop, low/med (cereal grains)	1.25	12,000	770	NA
Field/row crop, low/med (rice)	1.5	9,600	640	NA
Field/row crop, tall (corn) Pre-harvest rate for field corn Post-emergence rate for sweet corn	 1.5 0.5	 9,600 28,000	 2,400 7,200	 960 NA
Field/row crop, tall (sorghum)	1.0	14,000	3,600	NA
Sugarcane	2.0	NA	720	360
Turf - California Turf - North Carolina	2.0 2.0	3,300 1,500	NA NA	1,600 750
*Task descriptions for each crop and exposure scenario are included in Table 17.				

Table 19 - 2,4-D Postapplication Intermediate Term Worker Risks				
Crop Group	**Intermediate Term MOE on Day 0**			
	Application Rate+ (lb a.e./acre)	**Low Exposure Scenarios***	**Medium Exposure Scenarios***	**High Exposure Scenarios***
Field/row crop, low/med (cereal grains)	0.5	20,000	1,300	NA
Field/row crop, low/med (rice)	0.92	11,000	730	NA
Field/row crop, tall (field corn)	0.44	23,000	5,700	2,300
Field/row crop, tall (sweet corn)	0.48	22,000	5,500	NA
Field/row crop, tall (sorghum)	0.46	22,000	5,500	NA
Sugarcane	0.75	NA	1,300	670
Turf - California Turf - North Carolina	2.0 2.0	2,800 1,000	NA NA	1400 520
+ Average application rates as reported in the QUA report or NASS report were used when available. *Task descriptions for each crop and exposure scenario are included in Table 17.				

2.2.4 Risk Characterization

All of the post application MOEs are substantially greater than 100 which means that the risks are not of concern.

2.3 - Residential Applicator Exposures and Risks

According to the EPA Pesticide Sales and Usage Report for 1998/1999, 2,4-D is the most commonly used conventional pesticide active ingredient in the home and garden market sector with 7 to 9 million pounds applied per year. It is also the most commonly used conventional active ingredient in the Industry/Commercial/Government market section with 17 to 20 million pound applied per year. This segment includes applications to homes and gardens by professional applicators.

The residential products are typically formulated as dry weed and feed products or as liquids in concentrates or ready to use sprays. Many of these formulations include other phenoxy herbicides such as MCPP-p and MCPA. Both spot and broadcast treatments are included on the labels. Exposures are expected to be short term in duration for broadcast treatments because the label allows only two broadcast treatments per year. Exposures are also expected to be short term in duration for spot treatments because the labels recommend repeat applications for hard to kill weeds in two to three weeks.

2.3.1 - Scenarios, Data Sources and Assumptions

<u>Scenarios</u>

The following scenarios were assessed.

1 Hand Application of Granules
2 Belly Grinder Application
3. Load/Apply Granules with a Broadcast Spreader
4. Mix/Load/Apply with a Hose-end Sprayer (Mix your own)
5. Mix/Load/Apply with a Hose-end Sprayer (Ready to Use)
6. Mix/Load/Apply with Hand Held Pump Sprayer
7. Mix/Load/Apply with Ready to Use Sprayer

<u>Data Sources</u>

Exposure data for scenarios #1 and #2 were taken from PHED. Exposure data for scenarios #3, #4 and #5 were taken from the residential portion of the ORETF Handler Study (this study was discussed in Section 2.1.2.)

Exposure data for scenarios #6 and #7 were taken from the following study which has recently been purchased by the ORETF:

- **Carbaryl Mixer/Loader/Applicator Exposure Study during Application of RP-2 Liquid (21%) Sevin (r) Ready to Use Insect Spray or Sevin 10 Dust to Home Garden Vegetables.** Agrisearch Study No. 1519. EPA MRID 444598-01. Report dated August 22, 1998, Author; Thomas C. Mester, PhD., Sponser: Rhone Poulenc Ag Company

This study involved low pressure handwand and RTU trigger sprayer application of Sevin(R) which contains 21% carbaryl to home vegetable plants. Applications were made by volunteers to two 18 foot rows of tomatoes and one 18 foot row of cucumbers at a test field in Florida. A total of 40 replicates were conducted. Latex gloves were worn for twenty of the replicates and no gloves were worn for the other twenty replicates. Each replicate opened the end use product and applied it to the vegetable rows, after which the dosimeters were collected. Inhalation exposure was monitored in the breathing zone with personal air sampling pumps and OVS sampling tubes. Dermal exposure was monitored by the extraction of carbaryl from inner and outer cotton full body dosimeters, face neck wipes, and glove and hand washes.

The average field fortification recoveries for the full body dosimeters were 84.3% for the inner and 77.7 % for the outer. Face/neck wipe field recoveries were 84.8% and handwash and OVS tube field recoveries were greater than 90 %. Laboratory method validation for each sampling matrix fell within the acceptable range of 70 % to 120%. The limit of quantitation (LOQ) was 1.0 ug/sample for all media except the OVS tubes where the LOQ was 0.01 ug/sample.

Dermal exposure was determined by adding the values from the bare hand rinses, face/neck wipes, outer dosimeter lower legs and arms, inner dosimeter torso and inner dosimeter upper legs and upper arms. This accounts for the residential applicator wearing a short sleeved shirt and short pants. The unit exposures are presented in Table 20.

Table 20 - Unit Exposure Values For Trigger and Pump Sprayer Application (MRID 444598-01)

Scenario	Dermal Unit Exposure (mg/lb ai handled)			Inhalation Unit Exposure (ug/lb ai handled)		
	Average	Geo. Mean	Median	Average	Geo. Mean	Median
Trigger Sprayer	80	53	53	0.096	0.067	0.034
Hand Held Pump Sprayer	56	38	35	0.012	0.030	0.011

<u>Assumptions regarding Residential Applicators</u>

- Clothing would consist of a short-sleeved shirt, short pants and no gloves.
- Broadcast spreaders and hose end sprayers would be used for broadcast treatments and the other application methods would be used for spot treatments only.
- An area of 0.023 acre (1000 square feet) would be treated per application during spot treatments and an area of 0.5 acre would be treated during broadcast applications.
- The application rate is 2.0 lb ae/acre as listed on the master label.

2.3.2 Exposure and Risk Estimates

The MOE calculations are included in Appendix E and a summary is included in Table 21. All of the MOEs exceed the target MOE of 1000 and are not of concern.

Table 21 - 2,4-D Short Term MOEs for Homeowner Applications to Lawns			
Scenario	**Application Rate (lbs ae/acre)**	**Treated Area (acres/day)**	**MOE**
1 Hand Application of Granules	2.0	0.023	4,600
2 Belly Grinder Application	2.0	0.023	5,100
3. Load/Apply Granules with a Broadcast Spreader	2.0	0.5	38,000
4. Mix/Load/Apply with a Hose-end Sprayer (Mix your own)	2.0	0.5	2,300
5. Mix/Load/Apply with a Hose-end Sprayer (Ready to Use)	2.0	0.5	9,300
6. Mix/Load/Apply with Hand Held Pump Sprayer	2.0	0.023	15,000
7. Mix/Load/Apply with Ready to Use Sprayer	2.0	0.023	10,000
Note: 1000 square feet equals 0.023 acres			

2.3.3 Risk Characterization

The master label application rate of 2.0 lb ae/acre was used for all assessments. Many of the labels have application rates in the range of 0.5 to 1.5 lb ae/acre because 2,4-D is formulated with other phenoxy herbicides such as MCPP-p and MCPA.

2.4 - Residential Turf Post Application Exposure and Risks

2.4.1 Exposure Scenarios, Data Sources and Assumptions

The following exposure scenarios are assessed for residential post application risks

Toddlers Playing on Treated Turf
Adults Performing Yardwork on Treated Turf
Adults Playing Golf on Treated Turf

Data Sources:

There are three turf transferable residue studies that were submitted by the Broadleaf Turf Herbicide TTR Task Force. These studies were described in Section 2.2.2.

Overall Summary and Application of the TTR Data

Regression analysis of the TTR data is included in Appendix F and a summary of the data used for exposure assessment is included in Table 22. The maximum TTR value of 2.9% percent of the application rate is used for assessing acute exposures. The dissipation rate for humid regions without rain is derived from the North Carolina Phase 1 study in which the DMA form of 2,4-D was applied by itself. This dissipation rate is similar to the rates observed when the EHE form of 2,4-D was applied or when the DMA form of 2,4-D is applied with MCPP-p and dicamba. The dissipation rate for the dry regions is derived from the California TTR site data in which the DMA form of 2,4-D was applied with MCPP-p and dicamba. The dissipation rate for humid regions with rain is derived from the North Carolina Phase 2 data in which the DMA form of 2,4-D was applied with MCPP-p and dicamba.

Table 22 - Summary of TTR Data Used for Residential Post Application Exposure Assessment

	NC - Phase 1	NC - Phase 2	CA
Conditions	No Rain	Some Rain After DAT 2	No Rain
Application Rate (lbs ae/acre)	1.72	1.76	1.67
Maximum TTR (ug/cm^2)	0.56	0.25	0.24
Maximum TTR (% of applied)	2.9 - Note 1	1.3	1.3
Initial TTR (ug/cm^2)	0.31	0.20	0.20
Initial TTR (% of applied)	1.6 - Note 2	1.0 - Note 2	1.1 - Note 2
Semi-log Slope Factor	-0.83	-2.3	-0.26
Seven Day Average TTR (ug/cm^2)	0.080	0.034	0.10
Seven Day Average TTR (% of applied)	0.41 - Note 2	0.18 - Note 2	0.56 - Note 2
Days to LOQ	7	3	greater than 7

Note 1 - This value was used to assess 1 day acute and one day short term exposures.
Note 2 - These values were used to assess seven day average short term exposures.

General Assumptions

The following assumptions and standard values are taken from the Standard Operating Procedure (SOPs) of December 18, 1997 and ExpoSAC Policy #12 "Recommended Revisions to the Standard Operating Procedures for Residential Exposure Assessments of February 22, 2001.

- An assumed initial TTR value of 5.0% of the application rate is used for assessing hand to mouth exposures.

- An assumed initial TTR value of 20% of the application is used for assessing object to mouth exposures.

- Soil residues are contained in the top centimeter and soil density is 0.67 mL/gram.

- Three year old toddlers are expected to weigh 15 kg.

- Hand-to-mouth exposures are based on a frequency of 20 events/hour and a surface area per event of 20 cm^2 representing the palmar surfaces of three fingers.

- Saliva extraction efficiency is 50 percent meaning that every time the hand goes in the mouth approximately ½ of the residues on the hand are removed.

- Adults are assessed using a transfer coefficient of 14,500 cm^2/hour.

- Toddlers are assessed using a transfer coefficient of 5,200 cm^2/hour.

- Golfers are assessed using a transfer coefficient of 500 cm^2/hour.

- An exposure duration of 2 hours per day is assumed for toddlers playing on turf or adults performing heavy yardwork.

- An exposure duration of 4 hours is assumed for playing golf.

Assumptions Specific to 2,4-D

The following assumptions that are specific to 2,4-D are used for assessing residential post application exposures.

- The master label application rate of 2.0 lbs ae/acre was used.

- The exposure following the application of granular formulations was not assessed because there were no TTR data submitted for granular formulations. It was assumed this exposure would be less than or equal to the exposure from liquid formulations.

Calculation Methods

The above factors were used in the standard SOP formulae to calculate the exposures. These formulas are described in Appendix A. MOEs were calculated for acute toddler exposures using the maximum TTR value along with the acute dietary NOAEL of 67 mg/kg/day as selected by the HIARC (see Table 3). This NOAEL was adapted to acute dermal exposures by using the dermal absorption factor of 5.8 percent to account for route to route extrapolation. The MOEs for toddler short term exposures were calculated using the seven day average TTR value because the short term NOAEL was based upon decreased body weight gain which occurred after several days of exposure. MOEs for acute and adult short term exposures were calculated using the maximum TTR value because the acute and short term NOAELs are the same and are based upon the developmental effects which could have occurred following one day of exposure.

2.4.2 Exposure and Risk Estimates

The MOEs are summarized in Table 23 and 24 and the detailed calculations are included in Appendix G. All of the MOEs meet or exceed the target MOE of 1000.

Table 23 - Toddler MOEs for Exposure to Turf Treated with 2,4-D

	Application Rate (lbs ae/acre)	**TTR (ug/cm^2)**	**Semilog Slope**	**R^2**	**Dermal MOE**	**Hand-to Mouth MOE**	**Object to Mouth MOE**	**Soil Ingestion MOE**	**Total MOE**
Acute Toddler Risks Using the Maximum TTR (North Carolina Trial 1 using 2,4-D DMA)									
DAT 0	2.0	0.67 (MAX)	N/A	N/A	2,500	2,200	9,000	>100,000	1,040
Short Term Toddlers Risks Using California TTR Data (DMA Mix, No Rain)									
DAT 0 to DAT 6	2.0	0.12 (AVG)	-0.26	0.83	5,000	1,600	6,400	>100,000	1,000
Short Term Toddler Risks Using North Carolina TTR Data from Trial 1 (DMA and DMA Mix, No Rain)									
DAT 0 to DAT 6	2.0	0.093 (AVG)	-0.83	0.81	6,700	3,300	13,000	>100000	1,900
Short Term Toddler Risks Using North Carolina TTR Data from Trial 2 (DMA Mix, Some Rain)									
DAT 0 to DAT 6	2.0	0.039 (AVG)	-2.3	0.87	16,000	5,200	21,000	>100000	3,300
The acute NOAEL is 67 mg/kg/day for neurotoxic effects observed in acute neurotoxicity study. The short term NOAEL is 25 mg/kg/day for maternal effects observed in the developmental study.									

Table 24: Adult Acute/Short Term MOEs for Exposure to Turf Treated with 2,4-D			
Exposure Scenario	**Application Rate (lbs ae/acre)**	**TTR (ug/cm^2)**	**Acute/Short Term Dermal MOE[A] on Day 0**
Heavy Yardwork Playing Golf	2.0	0.67	1300 19000
A. The acute/short term NOAEL is 25 mg/kg/day for developmental effects observed in the developmental study.			

2.4.3 Risk Characterization and Comparison to Biomonitoring Data

Risk Characterization

The calculation of acute MOEs using maximum TTR value for toddler turf post application exposure represents a policy change because the maximum TTR values were previously only used to calculate short term MOEs. The 2,4-D risk assessment team decided that the previous approach would greatly overestimate the short term toddler risk because the short term endpoint was based upon maternal effects that would only occur after several days of exposure. The team also decided that the single day toddler exposures as represented by the maximum TTR values would be more appropriately assessed using the acute endpoint. The short term toddler exposures were assessed using the seven day average TTR values because the endpoint occurred after following several days of exposure and because the TTR data were collected during a seven day time period. The acute/short term adult exposures were assessed using the maximum TTR value because the acute/short term endpoint was a development effect that could have occurred following a single day of exposure. Although the developmental effect only applies to females of reproductive age, the Agency currently does not calculate separate MOEs for male and females because it not practical to exclude females from residential exposures.

The master label application rate of 2.0 lb ae/acre was used for all assessments. Many of the labels have application rates in the range of 0.5 to 1.5 lb ae/acre because 2,4-D is formulated with other phenoxy herbicides such as MCPP-p and MCPA.

The 2,4-D Task force has submitted a probabilistic assessment of residential exposure scenarios that was done using the Cumulative and Aggregate Risk Evaluation System (CARES) Model and this assessment is being reviewed by the Chemistry and Exposure Branch of HED. The CARES model itself has been reviewed by the FIFRA Science Advisory Panel.

Comparison to Biomonitoring Data

Researchers at the Canadian Centre for Toxicology conducted 2,4-D biomonitoring on adult volunteers who were exposed to 2,4-D while performing controlled activities for one hour on turf treated with 0.88 lb ae/acre 2,4-D (Harris and Solomon 1992). The controlled activities were conducted at 1 hour after treatment (HAT) and at 24 HAT. Ten volunteers participated in the study. Five volunteers wore long pants, a tee shirt, socks and closed footwear. The other five wore shorts and a tee shirt and were barefoot. The volunteers walked on the turf for a period of 5 minutes and then sat or lay on the area for 5 minutes and then continued in this fashion for 50 more minutes. At the end of the exposure period the volunteers were allowed to wash their hands and were served a picnic lunch on an adjacent unsprayed area. Each volunteer collected all urine for the next 96 hours immediately following the exposure. A baseline urine sample was also collected on morning of the exposure day to account for previous 2,4-D exposures and to use for spike samples. The spike samples were prepared by adding 22 ug of 2,4-D to 100 ml subsamples of the baseline urine samples and were stored by the volunteers in the same manner as the daily urine samples. The results indicated that detectable levels of 2,4-D were found only in the volunteers who wore shorts without shoes and who were exposed at 1 HAT. The highest exposure of 426 ug was detected in a HAT 1 volunteer who removed his shirt during the exposure period. The 1 HAT volunteers who wore long pants and shoes and all of the 24 HAT volunteers had urinary 2,4-D levels that were below the limit of detection of 5 ug/liter. The creatinine values, which were in the normal range and showed little daily variation, indicated that the urine collection was complete. The spike samples indicated an average recovery of 92.5 $\pm$ 14.5 percent. One of the 1 HAT volunteers and one of the 24 HAT volunteers had detectable levels of 2,4-D in the baseline sample.

As discussed in a recent review of pesticide biomonitoring (Maroni et al. 2000) most of the phenoxy herbicide dose is excreted in the urine as unmodified compounds or conjugate derivatives. As part of the skin absorption study of various pesticides including 2,4-D (Maibach and Feldmann, 1974) intravenous dosing was conducted to measure urinary excretion. One hundred percent (n=6) of the administered 2,4-D dose was recovered within 120 hours of administration and 98 percent of the dose was recovered within 96 hours. The dermal absorption portion of this study indicated that 5.8 $\pm$ 2.4 percent of the topical dose was recovered within 120 hours and 5.2 percent of the topical dose was recovered within 96 hours. In a more recent study of 2,4-D skin absorption (Harris and Solomon, 1992) 80.8 $\pm$ 13.3 percent (n=10) of the urinary excretion of a topically applied dose occurred during the first 96 hours and urinary 2,4-D was approaching the limit of detection at 144 hours. It should be noted that the applied dose (ug/cm^2) in the Harris and Solomon study was 280 times that of the applied dose in the Maibach and Feldmann study. The applied dose of in the Maibach study (4 ug/cm^2) is also closer to the estimated dermal exposure of 1.8 ug/cm^2 for a 70 kg adult with an exposed skin surface area of 11000 cm^2. The dermal exposure in ug = 0.672 ug/cm^2 * 2 hours exposure * 14500 cm^2/hr and the dermal exposure in ug/cm^2 = 19500 ug/11000 cm$^{2.}$

The results of the biomonitoring study were used to calculated MOEs by assuming that all of the urinary 2,4-D measured in the 96 hours after the exposure period was the result of the turf exposure. This assumption is protective because 2,4-D exposures due to inhalation and due to food and water ingestion would be counted as dermal exposure. The biomonitoring results were adjusted by a factor of two to account the SOP assumption of two hours of daily exposure vs one hour of exposure during the study and factor of 2.3 to account for an application rate of 2.0 lbs ae/acre vs 0.88 lb ae/acre applied during the study.

The MOEs for the DAT 1 volunteers who wore shorts and no shoes ranged from 1000 to 26000 with the lowest MOE corresponding to the volunteer who removed his shirt during the exposure period. The MOEs for the remaining volunteers ranged from 17000 to 27000. The MOEs are listed in Table 25.

Table 25 - Residential Post Application MOES on 2,4-D Treated Turf Based Upon Biomonitoring Data

Exposure Beginning at One Hour Post Application						
Volunteer	Clothing	BW	Measured 2,4-D Dose[A]	Adjusted 2,4-D Dose[B]	Adjusted 2,4-D dose	MOE[C]
1 2 3 4 5 Avg GM	shorts/barefoot shorts/barefoot shorts/barefoot shorts/barefoot shorts/barefoot[E]	100 kg 95.5 63.6 45.5 79.5	0.153 mg 0.020 (Note D) 0.020 0.103 0.426	0.70 mg 0.091 0.091 0.47 1.9	0.0070 mg/kg/day 0.00095 0.0014 0.0103 0.0244	3600 26000 17000 2400 1000 10000 5300
6 7 8 10 Avg GM	pants/shoes pants/shoes pants/shoes pants/shoes	77.3 kg 68.2 72.7 79.5	0.020 mg 0.020 0.020 0.020	0.091mg 0.091 0.091 0.091	0.0012 mg/kg/day 0.0013 0.0013 0.0011	21000 19000 19000 23000 20000 20000
Exposure Beginning at 24 Hours Post Application						
Volunteer	Clothing	BW	Measured 2,4-D Dose[A]	Adjusted 2,4-D Dose[B]	Adjusted 2,4-D dose	MOE[C]
1 2 3 4 5 Avg	shorts/barefoot shorts/barefoot shorts/barefoot shorts/barefoot shorts/barefoot	100 kg 77.3 63.6 79.5 72.7	0.020 mg 0.020 0.020 0.020 0.020	0.091mg 0.091 0.091 0.091 0.091	0.00091 mg/kg/day 0.0012 0.0014 0.0011 0.0013	27000 21000 17000 22000 20000 22000
6 7 8 10 Avg	pants/shoes pants/shoes pants/shoes pants/shoes	75 kg 67.3 65.9 100	0.020 mg 0.020 0.020 0.020	0.091mg 0.091mg 0.091mg 0.091mg	0.0012 mg/kg/day 0.0014 0.0014 0.00091	21000 18000 18000 27000 21000

Notes
A. Study conditions included one hour of exposure on turf treated with 0.88 lb ae/acre
B. Adjusted to account for two hours of exposure and an application rate of 2.0 lb ae/acre.
C. MOEs were calculated using a NOAEL of 25 mg/kg/day.
D. Measured doses of 0.02 mg represent non-detect values where the LOD is 5 ug/liter and the sample volume is 4 litres. The sample volume of 4 litres is based upon an average urinary output of 1 litre per day times 4 days.
E. This volunteer removed his shirt during the exposure period.

2.5 - Recreational Swimmer Post Application Exposure and Risks

The master label indicates that 2,4-D can be used for aquatic weed control of surface weeds such as Water Hyacinth and submersed weeds such as Eurasian Milfoil. Surface weeds are controlled by foliar applications at a maximum rate of 2.0 lb ae/acre. Submersed weeds are controlled by subsurface injection of liquids to achieve a target concentration of 2 to 4 ppm in the water column surrounding the weeds. This requires 5.4 to 10.8 lb ae per acre foot of water depth (i.e. 5.4 lbs ae would be required to achieve 2 ppm in a one acre pond that has an average depth of 1 foot). Granular formulations of BEE (Aquakleen and Navigate) are also used to control submersed weeds. The granular formulations are made with heat treated attaclay granules that resists rapid decomposition in water and release the herbicide into the root zone.

Although many herbicide treatments are applied to aquatic areas where recreational swimming is not likely to occur, some of the subsurface treatments are made at recreational lakes. These treatments are made because the Eurasian Milfoil interferes with recreation and other activities. This problem is particularly prevalent in the northern states such as Minnesota and Washington and in the New England region.

2.5.1 Exposure Scenarios, Data Sources and Assumptions

Scenarios

The following exposure scenarios are assessed for recreational swimmers.

Adult Recreational Swimmer
Child Recreational Swimmer

Assumptions

The following assumptions were used for the assessment of swimmer risks. Many of these assumptions were taken from the Residential SOPs and are also used in the SWIMODEL.

- The skin surface area of adults is assumed to be 21,000 cm^2 as cited in the Residential SOPs. This is the 95th percentile value for females (EPA Exposure Factors Handbook, 1997).
- The body weight for children is assumed to be 22 kg as cited in the Residential SOPs. This is a mean value for 6 year old children.
- The skin surface area for children is assumed to be 9,000 cm^2 as cited in the Residential SOPs. This is the 90th percentile value for male and female children.
- The assumed mean ingestion rate is 0.05 liters per hour for both adults and children as cited in the Residential SOP. This value may be greater for young children playing in water and accidentally ingesting a remarkable quantity of water (U.S. EPA SAP, 1999).

- The exposure time is assumed to be 3 hours per day. This is the 90th percentile value for time spent swimming in a freshwater pool. (EPA Child Specific Exposure Factors Handbook, 2002).
- The body weight for female adult acute exposures is assumed to be 60 kg.
- The body weight for male adult acute exposures is assumed to be 70 kg.
- The body weight for adult short term exposure is assumed to be 60 kg because the endpoint is gender specific.
- Risks were not calculated for foliar treatments because the application rate of 2.0 lb ae/acre would result in water concentration of only 0.25 ppm in a three foot water column even if all of the spray were to run off the leaves into the water.

<u>Calculation Methods</u>

The above factors were used in the SWIMODEL formulae for dermal and ingestion exposure which are described in Appendix A. The SWIMODEL formulas for the other dermal pathways (aural, buccal/sublingual and orbital/nasal) were not used because these formulas are based upon recreational swimmers in swimming pools who swim with their heads partially immersed. It is anticipated that recreational swimmers in weed infested areas would be less likely to swim with their heads immersed than recreational swimmers in weed- free swimming pools. In addition, the formulas for the buccal/sublingual and orbital/nasal pathways contain a default absorption factor of 0.01 which is based upon the absorption of nitroglycerin. This factor would greatly overestimate the risk of 2,4-D exposure because 2,4-D is absorbed at a much lower rate.

Because the 2,4-D water concentrations can vary depending upon the application rate and site conditions the Maximum Swimming Water Concentration (MSWC) was calculated. The MSWC is the water concentration at which the combined dermal and ingestion MOE meets or exceeds the target MOE of 1000. The MSWCs were calculated for children's acute exposures using the acute NOAEL of 67 mg/kg/day and the MSWCS for children's short term exposures were calculated using the short term NOAEL of 25 mg/kg/day for maternal effects. The MSWCs for adult acute/short term exposures were calculated using NOAEL of 25 mg/kg/day that is based upon the developmental effects which could have occurred following one day of exposure.

2.4.2 Exposure and Risk Estimates

The MSWCs are summarized in Table 26 and the detailed calculations are included in Appendix H. The acute MSWCs range from 1.2 ppm for 2,4-D BEE to 9.8 ppm for 2,4-D acid while the short term MSWCs range from 0.9 ppm for 2,4-D BEE to 3.6 ppm for 2,4-D acid or amine. The MSWCs for 2,4-D BEE are lower because 2,4-D BEE has a much higher dermal absorption value.

Table 26 - Maximum Swimming Water Concentrations for 2,4-D Aquatic Applications						
Exposure Duration	NOAEL (mg/kg/day)	2,4-D Form	2,4-D MSWC* (ppm)	Dermal MOE	Ingestion MOE	Combined MOE
Adults						
Acute/Short Term	25	Acid or Amine	9.8	97000	1000	1000
	25	BEE	1.2	1200	8300	1000
Children						
Acute	67	Acid or Amine	9.8	425000	1000	1000
Acute	67	BEE	2.4	1300	4100	1000
Short Term	25	Acid or Amine	3.6	230000	1000	1000
Short Term	25	BEE	0.90	1300	4100	1000
* The MSWC is the concentration below which the combined MOE would be above 1000 and the risks would not be of concern.						

2.5.3 Risk Characterization

The probability that a person would swim in an area recently treated for milfoil is low because milfoil forms dense mats of vegetation on the surface of the water which makes swimming difficult and unpleasant. This situation would occur prior to mid summer treatments when the milfoil has had time to grow. Early season treatments are recommended to prevent milfoil growth because milfoil is tolerant of cold water and will grow fast in the early spring when the lake water is still cold. In the case of early season treatments, the cold water would also reduce the time spent swimming.

The master label application rate is 5.4 to 10.8 lbs ae per acre foot for both liquid and granular formulations. This is not consistent with the existing granular labels which specify application rates of 19 to 38 lbs ae per acre. The Aqua-Kleen label, for example, specifies application rates of 19 to 38 lb ae/acre for control of susceptible weed such as milfoil and 28.5 to 38 lb ae/acre for slightly to moderate susceptible weeds such as water lilies. The higher rates are recommended when there are dense weeds, depths greater than 8 feet and large volume turnover. These rates correspond to water concentrations of 2.0 to 4.0 ppm using the master label application rate of 5.4 to 10.8 lb ae/acre foot and a depth of 3.5 feet. In cases where the depth exceeds 3.5 feet, the master label application rate would exceed the granular label rates. In testing the use of 2,4-D for use in managing Eurasian Watermilfoil in Minnesota, most treatments were done with 2,4-D BEE (i.e. Aqua-Kleen(R) or Navigate) an application rate of 19 lbs ae per acre. (Crowell, 1999). Practical experience from local applicators in Washington state has indicated than an application rate of 17 to 19 lb ae/acre (90 - 100 pounds of product per acre) may be more effective than rates of 200 pounds per acre due to a change in the plants physiology at higher rates (Washington State Dept of Ecology, 1998).

It is possible that 2,4-D concentrations may exceed 9.8 ppm for brief periods immediately after subsurface application before mixing has occurred. In the Minnesota lake study (MRID 458971-01), a maximum concentration of 13.2 ppm was measured at 1 HAT at one of the three sampling stations that were within the treated area while the average of the three stations was 4.5 ppm. By DAT 1, the maximum and average concentrations had declined to 2.7 ppm and 1.8 ppm. Many of the states require or recommend that a 24 hour swimming restriction be imposed following the aquatic application of 2,4-D for milfoil control. The Task Force has also amended the Master Label to include a 24 hour swimming restriction.

Field dissipation studies reviewed by EFED indicated that the 2,4-D half lives following the subsurface injection of 2,4-D liquid DMA to lakes and ponds ranged from 3.2 to 27.8 days. Summary data from these studies are included in Table 27 and more detailed information is included in Appendix I. The longest half life occurred following the second application to a 14 acre pond in North Dakota. The half life after the first application was 10.1 days. The diagram for this pond indicates that it had an inlet but no outlet and the water flow was not recorded. The seven day average 2,4-D concentrations were calculated using the study dissipation rates as shown in Table 28 and range from 1.4 ppm when the half life equals 3.2 days to 3.6 ppm when the half life equals 27.8 days. It should be noted, however, the target concentration for effective control is lower for the long contact times that correspond to the long half lives and in these cases, the lower end of the label rate range of 2 to 4 ppm could be effective. In the case of Eurasian watermilfoil, for example, severe milfoil injury occurred when exposed to 0.5 ppm for 72 hours, 1.0 ppm for 36 hours and 2.0 ppm for 24 hours (Green and Westerdahl, 1990).

Table 27 - Dissipation Studies Following the Subsurface Injection of 2,4-D DMAS

MRID	Location	Water Body Type	Size in Acres	Acres Treated	Application Rate (lb ae)	Treated Area Depth (feet)	Max 2,4-D Concentration (ppm)	Half Life (days)
458971-01	MN	Lake	1700	4.5	10.8 acre/foot	8.25	13.2	3.2
439083-02	ND - 1st App	Pond	14	14	41.8/acre	4 to 6	6.1	10.1
	ND - 2nd App			14	41.8/acre	4 to 6	4.2	27.8[A]
439547-01	NC - 1st App	Pond - Stream Fed	2.4	2.4	41/acre	3	2.5[B]	20.5[C]
	NC - 2nd App			2.4	41/acre	3	3.0	2.7

A. This half life is based upon Day After Application (DAA) 0 to 30.
B. This maximum concentration occurred on DAA 3.
C. This half life is based upon DAA 3 to 30.

Table 28 - Seven Day Average 2,4-D Water Concentrations

Half Life	Initial Concentration	7 day Average 2,4-D Concentration[A]
3.2 days	4.0 ppm	1.9 ppm
27.7 days	4.0 ppm	3.6 ppm
A. The 7 day averaging period includes day 1 to day 7. Day 0 is not included because a 24 hour swimming restriction has been added to the master label.		

The dermal exposures from 2,4-D BEE might be less than calculated because 2,4-D BEE degrades rapidly to form 2,4-D acid particularly when the ph is 7.5 or above. The half lives for BEE degradation in sterile water are 0.56 day at pH 8, 1.9 days at pH 7.5 and 5.1 days at pH 7.0 (Bothwell and Daley 1981). As shown in Table 29, these half lives correspond to seven day average 2,4-D BEE concentrations that are below the MSWC of 0.9 ppm when the initial 2,4-D BEE concentration is 3.0 ppm or less and the Ph is 7.5 or greater. These half lives also indicate that the 2,4-D BEE concentrations decline to the acute DWLOC of 1.2 ppm in <1 to 7 days depending upon the initial concentration and pH. In the BEE farm pond study (MRID 445250-01) where the ph was 8.0, the majority of 2,4-D detected after the application of granular BEE was the acid form. The maximum 2,4-D BEE concentration was 71.1 ppb while the maximum 2,4-D acid concentration was 3370 ppb.

Table 29 - 2,4-D BEE Conversion Times Based upon Abiotic Hydrolysis

pH	Ln Half Life (hrs)[A]	Half Life (days)	Slope Factor[B]	Initial 2,4-D BEE Concentration	Days Needed to Achieve Acute MSWC of 1.2 ppm	7 Day Avg 2,4-D BEE Concentration
8.0	2.6	0.56	-1.23	4.0 ppm	1	0.23 ppm
7.5	3.8	1.9	-0.37	4.0	4	**1.5**
7.0	4.8	5.1	-0.14	4.0	>7	**2.4**
8.0	2.6	0.56	-1.23	3.0 ppm	<1	0.18 ppm
7.5	3.8	1.9	-0.37	3.0	3	0.88
7.0	4.8	5.1	-0.14	3.0	7	**1.8**
8.0	2.6	0.56	-1.23	2.0 ppm	<1	0.12 ppm
7.5	3.8	1.9	-0.37	2.0	2	0.60
7.0	4.8	5.1	-0.14	2.0	4	**1.2**

Numbers in bold indicate 2,4-D BEE concentrations that exceed the short term MSWC of 0.9 ppm.

A. From Figure 11 of Bothwell and Daley, 1981
B. Slope Factor = -0.693/Half Life in Days

A study reviewed by EFED (Paris et. al. 1981) indicated that the average half life for the microbial degradation of 2,4-D BEE to 2,4-D acid was 2.6 $\pm$ 1.8 hours at a bacterial concentration of 5×10^{-8} organisms per liter. This study was based upon water samples drawn from 31 sites which included lakes, ponds, rivers and creeks located in the NE, SE, NW and SW regions of the US. The average half life for each site ranged from 1.2 ± 0.8 hours to 9.4 ± 7.8 hours. The average half life for each region ranged from 1.85 hours in the NW to 4.8 hours in the NE. The water temperatures ranged from 1 to 29 C with an average of 19 C and there was no correlation ($R^2 < 0.1$) between the temperature and the degradation rate constant. The pH ranged from 5.4 to 8.2, however, the pH was not reported for the individual sites. The bacteria concentration ranged from 4.8×10^5 to 9.8×10^8.

The EPA/ORD has recently completed the pilot phase of a study that will determine the ingestion rate of recreational swimmers. These rates are being obtained by measuring urinary cyanuric acid levels in swimmers after they swan in a cyanuric acid treated pool. The results for the 12 adult swimmers indicated that the average ingestion rate was 16 ml/hour and the maximum rate was 50 ml/hour. The results for the 41 children indicated that the average rate was 37 ml/hr, the 70^{th} percentile rate was 50 ml/hr and the maximum rate was 154 ml/hr. These rates might be overestimates because the other pathways, such as dermal and buccal, were not considered. The full study will include 600 swimmers.

3.0 - Data Compensation Issues

The TTR studies were submitted by the Broadleaf Turf Herbicide TFR Task Force. This task force includes many, but not all, of the 2,4-D registrants. There are data compensation issues regarding the use of the TTR data to support reregistration of products belonging to the 2,4-D registrants that are not members of the Broadleaf Turf Herbicide TFR Task Force.

Many of the occupational and residential handler scenarios were evaluated using unit exposure data that was submitted by the Outdoor Residential Exposure Task Force (ORETF). This task force includes many, but not all, of the 2,4-D registrants. There are data compensation issues regarding the use of the ORETF data to support reregistration of products belonging to the 2,4-D registrants that are not members of the ORETF.

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5.0 Glossary of Terms Used in Occupational/Residential Exposure Assessment

TERM	DEFINITION
Absorbed Dose	The amount of pesticide that is absorbed into the body.
AE - Acid Equivalent	The weight of 2,4-D excluding the weight of the ester or salt groups
AI	Active ingredient
DAT	Day after treatment
DFR - Dislodgeable Foliar Residue	The amount of residue that can transfer from treated crop foliage to human skin.
ExpoSac - Scientific Advisory Committee for Exposure	A committee within the EPA Health Effects Division that reviews pesticide exposure assessments and develops policy.
Exposure	The amount of pesticide that impinges upon the skin, is inhaled or is ingested.
Handler/Applicator	A worker who mixes, loads and/or applies pesticides
Intermediate Term	31 days to six months
LOAEL	Lowest Observed Adverse Effect Level
MOE - Margin of Exposure	The ratio of the “safe” dose (usually the NOAEL or the LOAEL) divided by the estimated exposure. Formerly called the Margin of Safety.
NOAEL	No Observed Adverse Effect Level
ORETF	Outdoor Residential Exposure Task Force
PCO	Pest Control Operator
PF5 Respirator	A filtering facepiece respirator (i.e. dustmask) that has a protection factor of 5 when properly fitted.
PF10 Respirator	A half face respirator with appropriate cartridges that has a protection factor of 10 when properly fitted.
Re-entry Worker	One who works in fields that have been treated with pesticides
REI - Restricted Entry Interval	The period of time that must pass following pesticide application before workers are re-enter the treated area.
PPE	Personal Protective Equipment
Short Term	One to thirty days
TTR - Turf Transferable Residue	The amount of residue that can transfer from treated turf to human skin.